FOREST CONDITIONS IN THE SIERRAS

By Wm. C. Hodge, Jr.

Introduction

The State of California has an area, in round numbers, of 100,000,000 acres, of which about one-third bears forest or brush cover, and one-sixth bears, or is capable of bearing, forests of merchantable timber. The forests lie mainly on the uplands, and the topography of the State is such as to dispose them in a belt which, beginning in the southern Sierras, stretches northward along their flanks, across the highlands at the head of the Sacramento Valley, thence southward nearly to San Francisco Bay; and brokenly thence along the coast ranges to the Mexico line, leaving the great interior valley and the depressions in the southeastern portion of the State unforested. Within this belt the forests are by no means homogeneous, but vary in character, composition, and density according to temperature and moisture conditions. These in turn vary from place to place according to elevation, latitude, and position relative to the sea. Differences in elevation, produce the most abrupt variations in climate, the effect on temperatures being the same in going from a low elevation to a higher as in going from south to north, but much more noticeable in comparison to the distance traveled. Both rainfall and the relative humidity of the atmosphere also increase in a marked degree with increase in elevation. Forest conditions are therefore similar for long distances horizontally, but change abruptly with change in elevation;

and the forest belts, taking their form from the topography, are in general long and narrow with a northwesteand-southeast trend.

Topography

In its broader aspects the topography of the State is quite simple. There are two main uplifts: the Sierra Nevada extending along the inland border in a southeasterly direction for two-thirds the length of the State; and the Coast System, composed generally of parallel ridges lower than the Sierra, extending thruout the State on its seaward side. Between these two systems, and further hemmed in on the north and south by ranges connecting them, is the great central valley. And beyond the mountains, in the southeast corner of the State, are the broad basins constituting the Mohave and Colorado deserts.

The Sierras are the highest mountains in the State. From Mount Shasta at the north, with an elevation of something less than 14,500 feet, to Mount Whitney, a trifle higher, 200 miles farther south, they extend in an almost continuous crest with an average elevation of more than 7,000 feet. The highest portion of the range is from Lake Tahoe to Mount Whitney, south of which the elevation gradually decreases. North of Lake Tahoe the system broadens out and consists of several ranges with occasional valleys intervening. South of Mount Whitney the Pah Ute and Greenhorn ranges parallel the main Sierra at intervals of about 15 miles, forming valleys thru which the two forks of the Kern River flow.

The topography of the northern Sierras is very broken. That of the southern Sierras is much more simple. The eastern

slopes of the range drop abruptly from the summit to a high arid plateau. The western slopes are longer and more gradual, tho broken at intervals by secondary divides and by tremendous river canyons.

Numerous rivers head in the Sierras. The most important of these on the west slope are: Pitt, Feather, Yuba, American, Cosummes, Mokelumne, Calaveras, Stanislaus, Tuolumne, Merced, San Joaquin, Kings, Kaweah, Tule, and Kern. The range is new, geologically speaking, and these rivers, almost without exception, flow for a part of their length thru deep canyons, of which the Yosemite Valley is perhaps the most famous. The waters of many of them are used in irrigating the valley land below, or for the generation of electric light and power.

The eastern slopes of the range give rise to few large streams. The principal ones are long Valley Creek, flowing out of Honey Lake; Truckee River, draining Lake Tahoe, Carson and Walker rivers, flowing northeastward into Nevada; and Owens River, flowing southeast into Owens Lake. Eagle Lake, Honey Lake, Lake Tahoe, Mono Lake, and Owens Lake all lie east of the Sierras. None of this water reaches the ocean, but all is either lost upon the desert or evaporates from the surfaces of the lakes.

The Coast System consists in general of parallel ridges, low but steep, extending northwest and southeast, often including fertile agricultural valleys, particularly about the middle of the range. Its rivers are usually small, but their water is very valuable, particularly toward the south where the climate verges on the arid.

North of San Francisco Bay, the mountains forming this system are known collectively as the Coast Range. Southward, they are given distinctive titles, as follows: Santa Cruz Mountains, north of Monterey Bay; Monte Diablo Range, separating Santa Clara Valley from the San Joaquin Valley; Santa Lucia Range, extending from Monterey Bay southeast to Santa Maria River, with the Gabilon Range paralleling it to the eastward. To the south are the San Rafael and the Sierra Madres trending easterly, the latter extending to Soledad Pass. The San Bernardinos stretch southeasterly from Soledad Pass, and beyond them are the San Jacintos and Cuyamaca Mountains.

The Coast Mountains gradually increase in elevation from north to south. North of San Francisco Bay the mean altitude of the ranges is about 2,000 feet. The San Rafael Mountains are higher, with a general elevation of about 5,000 feet, and a considerable portion of the San Jacinto lies above 7,500 feet, rising to nearly 11,000 feet in the San Jacinto Peak. The range is rough and rugged thruout.

At the head of the Sacramento Valley, and to the northwestward, is a jumbled series of ranges that extend across from the Coast System nearly to Mount Shasta. These mountains are exceedingly rough and irregular, with an average elevation of about 5,000 feet, the occasional peaks reach 8,000 feet. The principal ranges in the group are the Siskiyous, the Scott Mountains, the Marble Mountains, the Salmon Alps, and the Trinity Mountains. They contain very little agricultural land, but are forest land par excellence. They are drained by the Klamath and its

tributaries, namely, the Scott, Salmon, and Trinity rivers, and to some extent also by the Shasta River.

At the southern end of the great valley, in latitude 34°, the Sierras and the Coast ranges are connected by another cross range, the Tehachapis. These are much less in extent than the northern cross ranges and of less importance. Tehachapi Peak rises to an elevation of over 8,000 feet, but the mean altitude is about 5,000. The slopes of the range are largely desert in character.

The Great Central Valley is about 350 miles long and 40 to 60 miles wide, with an elevation ranging from sea level to 200 or 300 feet. It is drained from north and south of Sacramento and San Joaquin rivers, which unite just south of Sacramento and flow west into San Francisco Bay, thence into the ocean thru a break in the Coast Range known as Golden Gate. The floor of the valley is level or gently rolling, and the soil is exceedingly rich agricultural land.

The southeastern portion of the State consists of broad, deprest basins hemmed in by mountains, and with detached mountain ranges which trend generally northwest and southeast, rising abruptly from the floor of it. Portions of the desert are below sea level, while some of its mountains rise to 11,000 feet. The soil is fertile in many places, but the rainfall is insufficient to support anything but the scantiest growth, and altho it is cultivated here and there in spots and contains valuable mineral resources, an immense area must always remain unproductive because of the lack of moisture.

Relation to Climate

The topography of California is thus shown to consist essentially of alternate highlands and lowlands, parallel to the coast, the landward highlands having considerably greater elevation than the seaward. The prevailing movement of air over the State is from the west or northwest, that is, from the Pacific Ocean, the source of moisture. The effect of this arrangement on the rainfall is apparent. The air currents meet first the Coast Range as a barrier, and, being deflected upward, deposit some of their moisture, especially on the seaward slopes. Crossing the great valley they strike the Sierras, and after being wrung out once more, flow down the eastern slopes, having lost somewhat of their moisture, but being especially deficient in relative humidity. Considering that the rains have their origin in the north Pacific we should expect that the northwest portions of the State would be the wettest, and that the rainfall would decrease inland, except at constantly greater elevations, and also toward the south. This is precisely the case as the rainfall chart (Fig.) clearly shows.

The area of heaviest precipitation forms a belt which includes the northern Coast ranges, the mountains at the head of the upper Sacramento Valley, and the upper levels of the Sierras. It is surrounded below by successive belts of lighter precipitation which are fairly broad on gentle slopes, but narrow on the steeper slopes. Toward the southeast, and with lessening elevation, the precipitation constantly decreases until finally in the desert lowlands the precipitation for a whole year may be too small to be measured.

Thruout the whole State the humidity is low during the summer. Little or no rain falls between May and November, and the resulting aridity combined with the intense heat during summer are chiefly responsible for one of the most important of the forest problems, namely forest fire.

Forest Regions

The State divides itself naturally into three forest regions which may be designated the Redwood Belt, the Sierras, and Southern California. The first occupies a narrow strip of land along the northern coast, rarely extending inland more than 25 miles. The last includes the ranges south of the 35th parallel and the inner coast ranges north to San Francisco Bay. The "Sierra District" includes the Sierras proper, together with the Trinity, Scott, Siskiyou, and St. Helena ranges, and the Warner Mountains. The basis of this division lies to some extent in differences of forest composition, but especially in the differences of problems of forest management which each district presents.

The redwood belt and southern California are described in other reports. This report concerns itself solely with the Sierra district.

The Forest

The forests of the State are characteristically coniferous. Broad leaf species occur along streams and form open park like groves in valleys and on the lower foothills, and they are not lacking on the mountains as well. But the bulk of the protection forest and practically the entire commercial forest consists of coniferous species.

Foothill Forest

The foothill region with its semiarid climate has a characteristically open or brushy forest of low, branchy species. The relative humidity is comparatively low, and the rainfall less than 30 inches annually, occurring mostly in the winter. In consequence the soil, except near streams, is parched and dry during the growing season. Falls of snow are of rare occurrence and are very light, the snow seldom remaining on the ground for more than 24 hours at a stretch.

The soil comprizes clay volcanic sand, gravel, and various intermediate mixtures. The usual soil of the west slope of the Sierras is a gravelly or sandy loam. The volcanic soil is found mainly on the east slope of the Sierras and about the extinct volcanoes in the northern Sierras.

The foothill forest contains three principal species of trees, namely, valley white oak (Quercus lobata), blue or mountain oak (Quercus douglasii), and gray or digger pine (Pinus sabiniana). These occur together to some extent but their natural ranges differ slightly, and each has a tendency toward forming pure stands. Whether they are pure or mixt, the forests of the foothills are almost invariably open, the trees standing at wide intervals with brushy or grassy stretches between them. None of these species produce saw timber, with the possible exception of digger pine. On rare occasions it forms a clear bole to a height of 20 to 25 feet and in localities where better timber is wanting it is sometimes called upon to furnish rough material for local use. All three furnish fuel wood of somewhat

inferior quality, the oaks being preferred to the pine. Even when they grow in close stands these species are inclined to preserve their branchy habit. The pine is particularly remarkable as rarely assuming the coniferous form, but sends out stout branches from a short trunk. The stands of the oak species are decidedly orchard-like.

The valley oak has the lowest altitudinal range occurring at the valley levels and not extending far above them. As the digger pine seldom comes down to the valley level, these two species rarely mingle.

The range of the blue oak is somewhat higher, the species being rare at the valley level and particularly abundant on the lower foothills. It mixes with the valley oak on the one hand and with the digger pine on the other; but thruout the region of its best development it forms open stands of pure growth, and of strikingly picturesque appearance. (Fig.). There is a suggestion about the tree as if a white powder had been plentifully sprinkled over it, which gives the bluish cast to the foliage and the dead whiteness to the bark that render the tree unmistakable, even at a distance.

The digger pine occurs at the highest levels of the foothill belt, mingling with the blue oak below and with yellow pine, red fir, and other stragglers from the middle belt toward the upper limits of its range. It occasionally forms stands of a moderate degree of density, but more often the trees are distributed singly at wide intervals or in clumps of half a dozen. Like the blue oak, its foliage has a bluish or grayish

cast which gives it one of its alternative names--"gray pine". The other and more common name of "digger pine" comes from the fact that the large resinous seeds were formerly used for food by the digger Indians. They are borne in enormous cones which cluster along the branches, and are imperfectly concealed by the thin, straggling crown.

Other occasional members of the foothill forest are Gowen's cypress, buckeye, Christmas berry, red bud, and fremontia. Sycamore and willows occur where the presence of streams mitigates the extreme dryness of the average foothill soil.

The foothill forest, occupying the lower slopes, has comparatively little effect in regulating the run-off of streams; and containing no timber species, has small bearing on the timber supply. The principal use of it is as pasture, and in selected areas for ranching.

Yellow Pine Forest

The main body of commercial timber occupies the middle elevations. It lies between 1,500 and 5,000 feet in the northern ranges and between 4,000 and 8,000 feet in the southern Sierras. It has therefore an extreme altitudinal range of about 6,000 feet, but its average range at any particular latitude is from 3,000 to 4,000 feet. Its width varies from 15 to 35 miles, depending on the rate of slopes.

This forest yields abundant and valuable timber and is practically unbroken in extent. Yellow pine and sugar pine are the trees of first importance, and are usually associated with incense cedar, Douglas spruce, and white fir. The infrequent groves of bigtree occur at the upper levels within this belt.

The composition varies with soil aspect and elevation. The bulk of the merchantable timber is yellow pine which forms on the average, 30 to 50 per cent of the stand. Incense cedar comprizes 20 to 30 per cent; sugar pine, the stand of which is very variable, 5 to 25 per cent; Douglas spruce 5 to 15 per cent, decreasing in importance from north to south. Jeffrey pine, a close relative of yellow pine, occasionally forms 5 per cent of the stand on small areas; and the same applies to the stand of bigtree. Of less importance are black oak, tan oak, canyon live oak, yew, torreya, cottonwood, alder, dogwood, maple, service-berry, and various chaparral species that sometimes assume arborescent form. Yellow pine is well distributed thruout this merchantable belt of forest, but forms the largest percentage of the stand at the lower elevations. At the upper levels it is replaced to some extent by Jeffrey pine, and the sugar pine and white fir are relatively more abundant. Jeffrey pine does not occur below 6,000 feet, and white fir is represented below 5,000 feet only by scattered individuals. Douglas spruce has a wide distribution on north slopes in the northern part of the region, particularly in the Klamath basin. Here it often forms 50 per cent of the stand on the shady slopes of canyons, the sunny slopes being occupied by yellow pine. White fir and sugar pine also prefer the cooler, moister situations, hence their occurrence at the upper levels and on north slopes. Incense cedar has a distribution much like that of yellow pine.

The forest, as a rule, is rather open but the splendid development of the trees composing it permits a heavy stand of

timber. Good merchantable timber varies from 15,000 to 50,000 feet B. M. per acre, and average first-class virgin forest will yield about 25,000 feet. The forest consists of trees of all ages but the large trees have a disproportionately large representation. Most of the stands which have not been culled are long over-mature.

Sub-Alpine Forest

The upper levels of the merchantable timber belt are in reality a transition type connecting the yellow pine-sugar pine forest with t he fir-lodgepole forest above. The most important species of this last named forest are silver fir (Abies magnifica), lodgepole pine, (Pinus murrayana), and jeffrey pine, (Pinus jeffreyi). Occasional constituents are white fir (Abies concolor) and sugar pine, stragglers from below. The silver fir and jeffrey pine are also found occasionally in the yellow pine forest, and in places in the northern Sierras patches of lodgepole pine interrupt the extent of the yellow pine forest at the same elevation, the seldom mingling with it. At the highest elevations are found the typically sub-Alpine species, silver pine (P. monticola), foxtail pine (P. balfouriana), white bark pine (P. albicaulis), and black hemlock (Tsuga mertensiana).

The line separating the upper or fir-lodgepole forest from the middle or yellow pine-sugar pine forest being determined by moisture and temperature conditions, is neither very sharply defined nor very regular. It rises gradually from north to south, but dips down locally on north and east slopes, which, not receiving the direct rays of the sun, are usually cooler

and more humid than other exposures. The main east slope of the Sierras, however, is an exception to this rule, the moisture-bearing winds from the Pacific being shut off by the summit of the range. On the east slope of the Sierras, therefore, the upper belt is higher than it is on the west slope, the lower limit of it seldom going below 7,000 feet even in the northern Sierras. The forests of this belt are apt to be scattering and patchy. The silver fir tends to form pure stands, as does also the lodgepole. These pure stands are often of great density, particularly at the lower elevations, and are the only forests of the State outside of the redwood belt to form any considerable depth of humus. The pure stands are much interrupted by mixt open forests or by barren stretches, or where fire has destroyed the original forest, by chaparral. Chaparral species are found within all stands that are not dense enough to exclude them, and when fire kills the forest above them, they sprout and spread over the area. The principal high elevation species are Castanopsis sempervirens, Prunus demissa and Ceanothus.

Timberline lies at an altitude of about 8,000 feet in the northern cross ranges and at 10,500 feet to nearly 12,000 feet in the southern Sierras. This line is even more indefinite and irregular than the line between the yellow pine and fir forests. On the southwest slope of Mount Shasta, patches of white bark pine occur at an elevation of 9,800 feet and on Warren peak in northeastern Modoc County, the same species occurs up to 9,600 feet. Such cases, however, are merely sporadic and due to peculiarities of situation that do not hold thruout large areas.

Chaparral

The term "chaparral" comes from the Spanish and means literally a "thicket of evergreen oaks". In southern California it is sometimes used in this narrow sense to denote certain particular species composing the brushy growth. But it has also a broader signification, being used to designate dense, brushy growth of all descriptions, and this broader meaning is the one usually attached to it. The stand of chaparral varies considerably, both with the elevation and with the character of the forest under which it is found.

The chaparral of the upper and middle slopes of the Sierras is composed of various species of manzanita (Arctostaphylos), buck brush (Ceanothus), scrub oak, and wild plum and cherry (Prunus). Certain of these usually form a variable undergrowth in the timber and often occur in patches that contain no trees. On the foothills, in addition to Arctostaphylos, Ceanothus, and oaks, are found greasewood (Adenostoma), yerba santa, (Eriodictyon), mountain mahogany (Cercocarpus), coffee-berry (Rhamnus), and others of less importance.

On the foothills chaparral often forms the principal cover. The stand at the lower levels is rarely dense, and alternates with open stretches of grass. With increase in elevation there is usually an increase in the density of the chaparral up to the point where the commercial forest begins. In the open forest, chaparral still forms an interrupted ground cover but in the sense forest it may be entirely lacking. Patches of pure chaparral without trees occur thruout the Sierras,

particularly at the higher elevations. They almost invariably occupy situations that are capable of producing timber, and their origin lies in forest fires. The struggle for growing space between chaparral and timber is constant, especially at elevations of more than 5,000 feet, and the balance is, as a rule, nicely adjusted. When the natural balance is disturbed, as by fire or lumbering, a shifting takes place, and as the forest is usually the one to suffer by these disturbances of equilibrium, chaparral is increasing its area at an alarming rate. Where chaparral and timber occur together, the effects of severe or successive fires are to give increased light and growing space to the chaparral species which reproduce by sprouting, thru the removal of the trees, which reproduce only by seed. The chaparral therefore, increases in extent and density. Where fires occur in pure chaparral, however, they weaken and thin the stands of it, for some of the plants are certain to have been killed outright instead of merely being burned back, and there is no compensating betterment in growing conditions as there is where the chaparral grows beneath timber. Fires, therefore, first turn forested areas into chaparral areas and finally chaparral areas into grass patches or barrens. The "balds" or grassy-topped mountains of northern California originated in this way.

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White fir study, California

Upland type

Trees 2 inches and over in diameter breasthigh on 50 acres

Diameter breast-high	White fir	Incense cedar	Yellow pine	Red fir	Sugar pine	Black oak	Lodgepole pine	
Inches								
1 - 10	85.10	9.92	5.68	2.58	4.54	0.60	0.02	
12	3.00	.74	.40	.34	.44	..	..	
14	2.68	.44	.42	.28	.30	.02	..	
16	2.32	.52	.42	.22	.20	..	..	
18	1.64	.28	.34	.32	.12	..	..	
20	1.26	.38	.40	.34	.04	..	..	
22	1.50	.36	.34	.22	.22	..	..	
24	1.26	.36	.34	.38	.08	..	..	
26	.80	.22	.62	.28	.10	..	..	
28	1.14	.24	.28	.42	.12	..	..	
30	.74	.18	.30	.28	.24	..	..	
32	.74	.20	.08	.38	.12	..	..	
34	.64	.10	.14	.32	.10	..	..	
36	.46	.16	.40	.42	.14	..	..	
38	.22	.04	.06	.24	..	..	..	
40	.24	.08	.06	.24	.12	..	..	
42	.14	..	.04	.12	..	..	.02	
44	.12	.04	.04	.16	.08	..	..	
46	.18	.02	..	.10	.06	..	..	
48	.12	.06	.06	.20	.08	..	.02	
50	.08	.04	.12	.18	.04	..	.02	
52	.02	.02	.04	..	.04	..	..	
54	.04	.04	.06	.18	.04	..	..	
56	..	..	..	.08	.10	..	..	
58	..	..	..	.10	.04	..	..	
60	..	..	.08	.22	.08	..	..	Grand
61 - 84	.04	..	.04	.44	.14	..	..	total
Total	104.68	14.44	10.76	9.04	7.58	.62	.08	147.20
Per cent	71.11	9.81	7.31	6.14	5.15	.42	.06	100.00
Trees 12 inches and over in diameter breasthigh								
Total	18.02	4.26	4.92	6.28	2.84	.02	.06	36.40
Per cent	49.51	11.70	13.52	17.25	7.80	.06	.16	100.00
Trees 18 inches and over in diameter breasthigh								
Total	10.70	2.68	3.64	5.42	2.04	..	.06	24.54
Per cent	43.60	10.92	14.83	22.09	8.31	..	.25	100.00
Trees 24 inches and over in diameter breasthigh								
Total	6.40	1.60	2.60	4.48	1.72	..	.06	16.86
Per cent	37.96	9.49	15.42	26.57	10.20	..	.36	100.00

Stand tables, Butte County, California

Table 2.--Average of 20 acres, 2,500 feet elevation

	Yellow pine	Sugar pine	White fir	Douglas spruce	Incense cedar	Other species	Total
	Average number of trees per acre						
All diameters	50.65	6.15	0.45	32.35	10.45	18.90	118.95
Per cent	42.58	5.17	.38	27.20	8.79	15.88	100.00
12" and over	15.05	2.20	.10	6.20	1.60	12.15	37.30
Per cent	40.35	5.90	.27	16.62	4.29	32.57	100.00
18" and over	10.65	1.70	.10	5.50	.90	6.40	25.25
Per cent	42.18	6.73	.40	21.78	3.56	25.35	100.00
24" and over	6.90	1.55	.05	4.60	.65	2.65	16.40
Per cent	42.07	9.45	.31	28.05	3.95	16.15	100.00

Table 3.--Average of 20 acres, 3,500 feet elevation

	Average number of trees per acre						
All diameters	34.40	11.80	23.30	13.50	13.70	3.90	100.00
Per cent	34.19	11.73	23.16	13.42	13.62	3.88	100.00
12" and over	15.00	55.40	5.55	8.85	8.60	1.45	48.85
Per cent	33.45	12.04	12.37	19.75	19.18	3.23	100.00
18" and over	11.95	4.40	4.35	7.80	6.25	.45	35.20
Per cent	33.95	12.50	12.36	22.16	17.75	1.28	100.00
24" and over	9.10	3.75	2.95	6.30	4.20	.10	26.40
Per cent	34.47	14.21	11.27	23.86	15.91	.38	100.00

Stand tables, Butte County, California

Table 4.--Average of 22 acres, 4,000 feet elevation

	Yellow pine	White fir	Sugar pine	Incense cedar	Douglas spruce	Other species	Total
	Average number of trees per acre						
All diameters	59.17	23.81	23.67	20.16	6.10	16.78	149.59
Per cent	39.55	15.92	15.76	13.48	4.08	11.21	100.00
12" and over	14.87	7.27	6.61	4.84	2.31	8.28	44.18
Per cent	33.66	16.46	14.96	10.95	5.23	18.74	100.00
18" and over	11.60	6.26	5.59	3.43	2.08	4.26	33.22
Per cent	34.92	18.84	16.83	10.33	6.26	12.82	100.00
24" and over	8.91	5.25	4.68	2.61	1.98	1.85	25.28
Per cent	35.25	20.77	18.51	10.32	7.83	7.32	100.00

Table 5.--Average of 20 acres, 4,500 feet elevation

	White fir	Yellow pine	Sugar pine	Incense cedar	Douglas spruce	Other species	Total
	Average number of trees per acre						
All diameters	26.55	25.30	15.40	14.25	1.50	4.90	87.70
Per cent	30.27	28.85	17.56	16.25	1.48	5.59	100.00
12" and over	13.50	18.15	10.55	10.35	1.05	2.35	55.95
Per cent	24.13	32.44	18.85	18.50	1.88	4.20	100.00
18" and over	11.40	15.20	9.65	8.40	1.00	1.05	46.70
Per cent	24.41	32.55	22.66	17.99	2.14	2.25	100.00
24" and over	9.30	12.20	8.85	5.40	.90	.25	36.90
Per cent	25.20	33.06	23.98	14.64	2.44	.68	100.00

Stand tables, Butte County, California

Table 6.--Average of 20 acres, 5,000 feet elevation

Diameter breasthigh	White fir	Sugar pine	Yellow pine	Incense cedar	Other species	Total
Inches	Average number of trees per acre					
1 to 10	16.04	2.50	1.95	3.80	1.20	25.49
12	1.20	.70	.35	.20	.40	2.75
14	.70	.30	.15	.20	.25	1.60
16	1.00	.20	.40	.65	.05	2.30
18	1.50	.50	.25	.25	.20	2.70
20	1.55	.40	.45	.60	.10	3.10
22	1.05	.35	.50	.20	..	2.10
24	1.10	.45	.80	.30	.05	2.70
26	1.45	.70	.50	.60	.05	3.30
28	.85	.75	.70	.35	.05	2.70
30	.50	.30	.60	.50	..	1.90
32	.65	.35	.75	.45	.05	2.25
34	.60	1.20	.55	.45	.05	2.85
36	.75	.90	.50	.50	..	2.65
38	.70	1.10	.60	.25	..	2.65
40	.80	.90	.55	.20	..	2.45
42	.50	.55	.40	.25	..	1.70
44	.30	.80	.10	.05	..	1.25
46	.45	1.20	.55	.10	.05	2.35
48	.15	.95	.25	.10	..	1.55
4 to 6	.65	3.15	.45	.25	..	4.50
6 to 8	..	.50	..	..	..	.50
Total	32.49	18.65	11.45	10.25	2.50	75.34
Per cent	43.13	24.75	15.20	13.61	3.31	100.00
	Trees 12 inches and over in diameter breasthigh					
Total	16.10	15.90	9.40	6.40	1.15	48.90
Per cent	32.89	32.48	19.20	13.08	2.35	100.00
	Trees 18 inches and over in diameter breasthigh					
Total	13.05	14.65	8.45	5.25	.50	41.90
Per cent	31.15	34.96	20.17	12.53	1.14	100.00
	Trees 24 inches and over in diameter breasthigh					
Total	8.90	13.50	7.00	4.25	.25	33.90
Per cent	26.25	39.82	20.65	12.54	.74	100.00

Stand tables, Calaveras County

Sugar pine - Yellow pine type

Average of 512 acres at 5,000 feet elevation

Diameter breast-high	White fir	Cedar	Sugar pine	Yellow pine	
Inches					
1 - 6	111.35	48.75	35.58	18.80	
6 - 14	9.30	1.81	1.80	3.17	
16	1.05	.25	.20	.22	
18	.70	.30	.19	.21	
20	.63	.22	.17	.18	
22	.40	.18	.17	.15	
24	.39	.19	.13	.13	
26	.40	.28	.15	.12	
28	.44	.21	.15	.13	
30	.38	.22	.15	.13	
32	.38	.19	.12	.15	
34	.42	.21	.12	.13	
36	.44	.32	.14	.15	
38	.42	.28	.11	.16	
40	.45	.26	.10	.14	
42	.35	.18	.13	.09	
44	.31	.13	.09	.11	
46	.29	.18	.16	.11	
48	.27	.11	.12	.12	
50	.21	.10	.14	.13	
52	.18	.07	.14	.06	
54	.12	.04	.13	.09	
56	.10	.05	.17	.06	
58	.06	.02	.12	.03	
60	.08	.03	.19	.02	
61 - 80	.05	.05	.48	.05	Grand
81 - 130	.01	..	.18	.01	total
Total	129.14	54.61	39.33	24.85	247.93
Per cent	52.09	22.03	15.86	10.02	100.00
Trees 18 inches and over in diameter breasthigh					
Total	7.24	3.70	3.68	2.58	17.20
Per cent	42.09	21.51	21.40	15.00	100.00
Trees 24 inches and over in diameter breasthigh					
Total	5.54	3.04	3.16	2.07	13.81
Per cent	40.12	22.01	22.88	14.99	100.00

Stand tables, Madera County, California

Table 8.--Average of 20 acres, 3,000 feet elevation

	Digger pine	Yellow pine	Black oak	White oak	Cedar	Buckeye	Total
	Average number of trees per acre						
All diameters	28.95	12.60	13.15	1.20	0.05	0.05	56.00
Per cent	51.70	22.50	23.48	2.14	.09	.09	100.00
12" and over	9.65	4.60	6.35	.35	..	.05	21.00
Per cent	45.95	21.90	30.24	1.67	..	.24	100.00
18" and over	2.30	2.30	3.25	.30	..	..	8.15
Per cent	28.22	28.22	39.88	3.68	..	..	100.00
24" and over	.95	1.20	1.85	.20	..	..	4.20
Per cent	22.62	28.57	44.05	4.76	..	..	100.00

Table 9.--Average of 20 acres, 4,000 feet elevation

	Yellow pine	Sugar pine	Incense cedar	Black oak	Total
	Average number of trees per acre				
All diameters	80.60	3.55	47.40	6.80	138.35
Per cent	58.26	2.57	34.26	4.91	100.00
12" and over	38.20	2.15	19.05	5.45	64.85
Per cent	58.90	3.32	29.38	8.40	100.00
18" and over	26.45	1.40	14.05	3.35	45.25
Per cent	58.45	3.10	31.05	7.40	100.00
24" and over	14.50	1.30	9.80	1.60	27.20
Per cent	53.31	4.78	36.03	5.88	100.00

Stand tables, Madera County, California

Table 10.--Average of 80 acres, 5,000 feet elevation

Diameter breasthigh	Yellow pine	Sugar pine	White fir	Incense cedar	Black oak	Total
Inches	Average number of trees per acre					
1 to 10	6.35	7.95	11.85	16.90	0.30	43.35
12	.90	1.00	1.05	2.10	.40	5.45
14	.90	.50	.50	1.70	.35	3.95
16	1.70	.15	.35	1.60	.30	4.10
18	.65	.40	.55	1.20	.25	3.05
20	.55	.70	.30	1.10	.20	2.85
22	.90	.25	.35	1.05	.10	2.65
24	.90	.45	.60	1.50	.10	3.55
26	.50	.35	.80	1.05	.05	2.75
28	.80	.45	.55	.75	..	2.45
30	.75	.55	.60	1.40	.05	3.35
32	.45	.25	.80	1.35	..	2.85
34	.45	.55	.90	1.00	..	2.90
36	.70	.40	.80	1.20	.10	3.20
38	.30	.50	.90	.75	..	2.35
40	.40	.45	.80	.75	..	2.40
42	.70	.65	.50	.40	..	2.25
44	.40	.30	.65	1.10	..	2.45
46	.65	.35	.40	.55	..	1.95
48	.45	.40	.55	.30	..	1.70
4 to 5	1.10	2.35	.65	.70	..	4.80
5 to 7	.50	.30	..	..	..	.80
Total	20.60	19.25	24.60	38.45	2.30	105.25
Per cent	19.62	18.29	23.37	36.53	2.19	100.00
	Trees 12 inches and over in diameter breasthigh					
Total	13.75	10.70	12.25	20.25	1.65	58.60
Per cent	23.46	18.26	20.90	34.56	2.82	100.00
	Trees 18 inches and over in diameter breasthigh					
Total	10.35	9.40	10.65	15.35	.70	46.45
Per cent	22.28	20.24	22.93	33.04	1.51	100.00
	Trees 24 inches and over in diameter breasthigh					
Total	8.35	8.20	9.10	12.10	.25	38.00
Per cent	21.97	21.58	23.95	31.84	.66	100.00

Description of Species

Yellow Pine (Pinus ponderosa)

Yellow pine occurs scatteringly in the northern Sierras at 1,500 feet elevation, mingling at this level with digger pine. At 2,000 feet the stand is denser and the development of the individual trees better, and from this elevation up to 5,000 feet the finest stands occur. In the southern Sierras it is seldom found below 3,500 feet and commercial forests lie mainly above 4,500 feet, and thence up to 8,000.

Within its range, yellow pine occurs on all soils, and on slopes having various degrees of inclination and aspect. It is a light-loving tree, however, and can endure a dry soil, and is therefore less abundant on north slopes. It reaches its best development on the west slopes of the Sierras, and especially in the plateau region about Mount Shasta. Here it forms 30 to 90 per cent of the stand, and exceptional areas yield as much as 150,000 feet per acre. Southward on the Sierras the development of individual trees is often as good but the proportion of yellow pine in the stand is apt to be less, and the yield of this species per acre, consequently, not so large.

Yellow pine assumes a wide variety of forms, which depend largely upon the character of the situation in which it occurs. Under the best conditions it is a tall, rather full-boled tree, and has a height, when mature, of from 175 to 200 feet, and a maximum diameter of from 6 to 7 feet. A very noticeable feature in the development of the tree is its persistent height growth; that is, it never runs to limbs even when grown

in the open. The limbs persist well toward the ground in such cases, but usually remain small. The mature trees have a very heavy, yellowish bark, with rather smooth, large, irregular plates. The bark is often from 2 to 3 inches thick.

The root system of the yellow pine is somewhat deeper than that of the sugar pine, altho the mature trees have very little, if any, taproot. The young seedlings, however, develop a long taproot, especially in dry situations. In such places the growth below ground during the first year will sometimes be two or three times that above ground. Later, however, the tree develops a strong lateral root system which renders it very wind firm.

Yellow pine is not fastidious in its demand upon soil moisture. Its remarkable ability to stand drought and to occupy unfavorable locations are factors which largely explain its wide range. It does best, however, on a rather loose, sandy loam or gravelly loam soil that is well watered and well drained. In the Sierras such conditions are found on the beds of the old filled-in lakes. Often yellow pine will be found growing well on very dry soil, such as the glacial drift of the Shasta Plateau, but it is probable that the subsoil is well watered there and that the depth of the tree's root system renders accessible a good supply of moisture.

The yellow pine is decidedly a light-loving tree; even a slight degree of shade perceptible retards its growth. But the hardy nature of the species seems to permit it to survive for a longer period under shade than some trees no less tolerant.

If not shaded too long it will recover, but shade-grown trees are always more spindling in form and show a decided suppression in height growth. The ability of yellow pine to withstand drought makes it capable of enjoying full sunlight from the start. A scale of tolerance for the coniferous species of the Sierras, beginning with the most tolerant, would be: incense cedar, white fir, Douglas spruce, yellow pine, sugar pine.

Next to incense cedar yellow pine is the most prolific seed bearer of the Sierra conifers. Moreover, there seems to be a large degree of regularity in the occurrence of seed years. Heavy seed years occur about once every three or four years. Unlike the sugar pine, however, yellow pine bears very little seed during the intermediate years.

The seed of the yellow pine is well scattered, and a single tree is often able to seed up a considerable area. The trees begin bearing seed at a much earlier age than sugar pines, but trees under 12 or 14 inches in diameter seldom bear very heavily.

The seed is shed in the fall and usually germinates the same season. Yellow pine is not very particular about seed bed and may be found germinating on the bare mineral soils, but the germination is much better where the seed bed contains more moisture. Often on lumbered areas within the virgin forest it will be found that young seedlings are much more abundant on the patches of squaw carpet (Ceanothus prostratus) than elsewhere. This is undoubtedly due to the moisture-retaining qualities of this form of ground cover. Yellow pine seed has a fairly high

percentage of germination. Tests made by the Forest Service place it at about 70 per cent.

As might be expected from the seeding capacity and hardy character of the species, reproduction and second growth are abundant wherever light is plentiful and seed trees present, provided, of course, fire is absent. Yellow pine may be found reproducing even under the heavy virgin stands, but lack of light prevents its surviving beyond the first few years. Under partial shade the yellow pine will hang on in a suppress condition much longer, but it is in the large openings made by lumbering or fire that reproduction is at its best. The full light to which the species is partial and its ability to withstand drought, combined with its rapid height growth, render it particularly adapted to occupy such areas, oftentimes to the exclusion of almost all other species. It is this fact that either has entirely changed or is changing the character of the stand on areas where lumbering is carried on, so that the relative amount of yellow pine in the future Sierra forests bids fair to greatly exceed that in the present virgin stand.

In its power to resist fire, yellow pine surpasses all its associates. The young trees, as in the case of other species, are easily killed or permanently injured by fire, but with the larger and mature trees the thickness of the bark is an excellent protection against ground fires, and even after the bark has been burned thru on one side the tree usually continues to thrive. Mature trees are sometimes killed by fire, or sufficiently injured by it to fall victims to insect attacks, but this is

the case only when the fire is excessively hot and the crown is more or less affected.

While not so free from injury by natural enemies as the sugar pine, yellow pine does not, as a rule, suffer greatly in this way. Wind does very little damage to the species. Windshake is not common, and, outside of a few very exposed ridges, the total effect of wind on the tree is so slight as to scarcely deserve mention. Yellow pine often suffers, however, from fungous diseases. Among the mature trees conk, or red heart, is fairly common, and very old trees which have been injured by fire will almost invariable be found to be more or less affected by red heart, which is due to a fungus (Trametes pini). Generally, however, the yellow pine, except overmature trees and those that have suffered from some other form of injury, seems to be exceptionally free from fungus diseases within its California range.

Like the other Sierra conifers, the yellow pine is a host plant for the parasite Arceuthobium occidentale. It is more subject to it than sugar pine, tho less so than cedar or fir. Most of the damage done is to the limbs, which become crooked and gnarled and eventually die.

Yellow pine suffers from insect attacks probably more than any other western conifer. Doctor Hopkins says of it in his report on his western trip:

"It has in Dendroctonus brevicomis a most pernicious enemy, which penetrates and excavates winding galleries thru the living bark of the finest trees, speedily causing their death. Very many trees have died and are dying from this cause, and the dead ones are contributing to the spread of forest fires. Its next greatest enemy is the pine butterfly, which has from time to time defoliated and caused the death of much of the best yellow pine timber in eastern Washington and in Idaho.

There are many secondary enemies of greater or lesser importance among the Scolytid genera Pityophthorus, Pityogenes, Xyloterus, Tomicus, Hylastes, and Hylurgops, which contribute to the death of trees primarily injured by defoliating and other insects, fire, and other causes. Numerous Buprestid and Cerambycid enemies of the wood and bark contribute to the unhealthy condition of the timber and the destruction of the wood. Coleopterous larvae infest the terminal twigs of young trees near Moscow, Idaho, and one or more Curculionid beetles breed in the bark at the base of young and old trees."

The Dendroctonus mentioned by Doctor Hopkins has already done considerable damage in the neighborhood of McCloud, Cal., and has commenced its depredations in the Yosemite region. Tomicus confusus, the species which kills fire-injured young sugar pines, is also found in young thickets of yellow pine wherever fire has injured them.

It seems probable that in the near future the frequency of insect attacks on the yellow pine will become a very serious factor in dealing with the forests, since their relation to lumbering and fire is such that in many places the conditions are ripe for their increase. Yellow pine when growing pure seems in greater danger of widespread destruction than when mixt with other species, and the increasing number of pure yellow pine stands is an additional menace of danger from this source.

Aside from the three sources of injury already mentioned, yellow pine has few enemies, nor does it suffer much from grazing or the like. An injury, the cause of which has ceased but the effect of which is still visible in Butte and Tehama counties, is that caused by boxing. During the civil war most of the yellow pine in the region was boxed for turpentine, the high price of which made this a profitable undertaking. After the war, when the price for turpentine was again normal, it

ceased to be profitable to exploit the western yellow pine for this purpose. The quality of the timber cut from these boxed trees, however, has been greatly lowered, owing to this early boxing.

Jeffrey Pine (Pinus jeffreyi)

Jeffrey pine occurs in the merchantable timber belt where it reaches its best development and becomes a timber tree, but is numerically unimportant; and in the upper belt where it often forms a considerable proportion of the forest. Its altitudinal range is between 5,000 and 8,000 feet in the northern cross ranges and northern Sierras, between 6,000 and 9,000 in the southern Sierras, extending up to 10,000 feet in places on the east slope. It is much more common on the eastern slope of the Sierras and toward the southern limit of the range than northward and largely replaces yellow pine in these localities.

In the merchantable timber belt, Jeffrey pine seldom forms more than 5 per cent of the stand, and is entirely absent thruout large areas. Where it occurs it is associated with yellow pine, sugar pine, and white fir, It reaches a height of nearly 175 feet and a diameter of 5 feet, developing a long, straight, cylindrical bole, clear to a height of 60 feet or more, and produces valuable lumber.

In the upper zone of forest, it occasionally forms patches of pure forest, but more often is a constituent of the mixt forests of California red fir and lodgepole pine. The development at high altitudes is much inferior to that at lower levels. In the upper belt it rarely exceeds 50 feet in height ,

or 3 feet in diameter. Its clear bole is comparatively shorter still, and its large crown is borne by branches disproportionately stout. It is also shorter-lived than in the lower zone, 200 years being as a rule the maximum, while in the lower zone it may reach an age of double that.

It grows in all situations and on all soils, or even in crevices between the rocks where soil appears to be absent. Wherever the soil is fairly deep it tends to form forests of considerable density. In other places its occurrence is more scattered.

In its reproduction it proves itself to be a characteristic tree of the Alpine zone rather than of the mountain zone. In the latter, altho seedlings are present everywhere, they are extremely scattered and are much less numerous than those of any other important tree of the zone. In the Alpine zone, on the other hand, they are exceedingly abundant, and form a significant part of the young growth in the Alpine forests.

The seed is borne abundantly in the upper zone, and sprouts readily in all situations. The rapid growth of the seedlings, and their ability to endure both shade on the one hand and drought on the other, are ample warrant that the representation of this species in the future forest will be adequate.

This species suffers more or less from fire. In early youth it is not so susceptible as the fir or the lodgepole pine, but in later years, by reason of the resinous quality of its wood, it is comparatively more so.

It also suffers somewhat from windfall, due both to its habit of growing in exposed situations, and on this soil which affords too feeble a foundation for it.

Sugar Pine (Pinus lambertiana)

The range of the sugar pine lies within that of the yellow pine, but is much more restricted. The difference in distribution is less noticeable if we consider California simply, than if we consider the entire ranges of the two trees. Sugar pine is found on most of the mountains of California above certain minimum elevations, but extends northward only as far as central Oregon and southward, scatteringly, into lower California; whereas, yellow pine is widely distributed not only in California but on the eastern slopes of the Cascades in Oregon and Washington and thruout the Rocky Mountain region. The altitudinal range of sugar pine varies between limits of 2,000 and 6,000 feet in the northern Sierras, and 5,000 to 9,000 and over in the southern Sierras and Sierra Madres. Its best development is reached at altitudes of between 3,000 and 7,000 feet, according to the latitude. It does not cross the Sierras to the eastern slope except in the southern portion of the Truckee basin where a few scattered trees occur. It is found on the coast ranges in eastern Mendocino County and is distributed northward over the South Fork, Trinity, Scott, Salmon, and Siskiyou mountains. It also occurs in southern California, on the Santa Lucia mountains, and thence southward.

It prefers cooler and moister situations than yellow pine, exhibiting a preference for north and east slopes with red

fir and white fir, and forsaking the sun-baked south and west slopes. It also ranges higher than the yellow pine, seldom, indeed, occurring much above the extreme upper limit of the latter, but forming a greater proportion of the stand toward its own upper limits than toward its lower. It nowhere forms forests of pure growth. On rare occasions it may form 50 per cent of the stand on a very limited area, but its average representation is from 5 to 20 per cent, and the latter figure is perhaps excessive.

It is more fastidious than yellow pine in almost every respect, and in fact responds more quickly to unfavorable growing conditions than almost any other tree in the forest. It is particularly unsatisfactory in its habits of reproduction. Seed is not borne yearly but at 2 to 3 year intervals. The cones require two years to ripen, being exposed meanwhile to the various natural vicissitudes that may occur. Squirrels and insects thus ruin large quantities of seed that never mature. Many of the seeds that reach the ground fail to sprout for diverse reasons. The seeds are very oily and often spoil before they sprout. They have thin shells that offer no protection at all to fire, and very little to the heat of the sun. And, most of all, they are extremely particular as to seedbed, requiring a fresh soil containing humus.

Sugar pine prunes itself well, surpassing the eastern white pine in this respect. This is an important factor in the value of the tree for lumber, since it enables it to form a clean stem much earlier in life. At maturity the sugar pine has a long, clean, symmetrical, and rather slowly tapering bole, surmounted by a flat, spreading crown.

The height growth of sugar pine is rapid, and the mature trees usually tower slightly above the rest of the forest. The tree has an average height of from 150 to 175 feet and a diameter of from 4 to 5 feet, altho it may attain a maximum height of 235 feet and a diameter of 12 feet. At no period of its life does sugar pine have a deep root system, tho that which it has is strongly developed and wide spreading, so that in spite of the absence of a taproot the tree is very wind firm.

In its demands upon the soil sugar pine is never very fastidious. The principal soils of the region in which it occurs are a rather light, loamy, or sandy soil resulting from the decomposition of outcropping schistose rocks, and a loose, rather coarse, gravelly soil, which results from the breaking down of the granite backbone of the Sierra Range. On both of these soils the sugar pine grows equally well, provided they are well drained, of sufficient depth, and not too dry. A third soil, and one to which it does not take so readily, is found in the Shasta region. It is a loose, dry, glacial drift, underlain by a subsoil of decomposed lava. The scarcity of sugar pine on this soil is, however, undoubtedly due to the extreme dryness of the surface soil, for on exactly similar soils where moisture is more abundant the tree is very thrifty. Sugar pine is found most often and does best in situations with moist atmosphere, where transpiration is slow, hence its preference for cool north and east slopes and heads of gulches and canyons. As might be expected from this, the sugar pine is unable to stand drought, especially when young, a fact that is of great importance in the reproduction of the species.

The sugar pine is an intolerant tree, possibly the most so of any of the Sierra conifers. It can not attain full development without an abundance of light, and is invariably suppresst or killed under heavy shade. In early youth, however, it is to a certain extent shade demanding, and in full light is apt to be stunted or even killed. The moister the air, of course, the less apparent is this shade-demanding quality, and on cool northern slopes young trees will sometimes thrive without any protecting shade. As it grows older the tree demands more and more light, and is usually seen with its crown fully exposed.

A scale of tolerance for the coniferous species of the Sierras beginning with the most tolerant would be: incense cedar, white fir, Douglas spruce, yellow pine, sugar pine.

The two pines are very close together in tolerance, but on the whole the yellow pine seems to stand suppression rather better than does sugar pine, hence it is placed ahead of it on the list. Both rank as intolerant species, while incense cedar and white fir are tolerant species, and Douglas spruce can hardly be called either tolerant or intolerant.

The sugar pine does not produce seed as early in life as do the other Sierra conifers. It is seldom that a tree less than 16 inches in diameter bears cones, and usually only trees 20 inches or more in diameter bear to any considerable extent. This species, moreover, is neither a regular nor a prolific seeder at any period of its life. Individual mature trees, it is true, often bear seed steadily, but in small quantities compared with either incense cedar or yellow pine. There are undoubtedly, at intervals,

extra heavy seed years for sugar pine, but that there is any general regularity in their recurrence is extremely doubtful. Locally good seed crops occur at intervals of five to seven years, but sugar pine will be found seeding a little every year.

In distributing its seeds the sugar pine, thanks to its height, can cover a considerable area, tho this is somewhat offset by the size and weight of the seeds, which prevent very wide distribution by the wind. Ordinarily a tree will seed up the ground thoroly at a distance from its base equal to its height. Wind, slope,and water can often be depended on to greatly increase this distance.

The sugar pine is not only the least prolific seed bearer, but it is one of the most particular species as to seed bed. It prefers a moist, rather loose, bed on which to germinate, such as the natural duff or humus of the forest floor affords, and will seldom germinate on bare mineral soil. The condition of the ground after fire is hardly favorable to sugar pine germination. Under even the best conditions sugar pine seed has not a high per cent of germination. Tests made by the Forest Service, under favorable conditions, place it at about 25 per cent; under natural forest conditions it would be less than this. The cones requiring two years to ripen are exposed during this period to various accidents. A large number of seeds are destroyed by squirrels and ground mice, the squirrels often stripping a tree of its cones before they are ripe and leaving a large part of the seeds to rot in the cones on the ground. The seeds are very oily and often spoil before they have an opportunity to sprout. They

have thin shells that offer no protection at all to fire and very little to the heat of the sun. These facts explain to a large extent the scarcity of sugar pine reproduction. And when it is remembered that the seeds require a fresh humus soil in which to sprout, that the young seedlings after having sprouted require abundant sunlight, and, finally, that thruout the range of sugar pine the moist situations are almost invariably shady, the difficulty of reproducing this species is more fully realized.

Sugar pine seedlings are often found, to be sure, under the virgin stands, but they are never very abundant. The conditions of seed bed here are usually favorable to germination, but the shade is too heavy and in a short time the young trees suffer from suppression, and soon die. In small openings in the virgin stand and along the edges of roads or broad trails cut thru the virgin forest the conditions for sugar pine seem most favorable. Such openings are usually very quickly filled with young growth of all species, but the protection afforded by the side shade and the stimulation to rapid height growth from the overhead light are just the conditions that favor sugar pine, and its rapidity of height growth enables it to outstrip all competitors and ultimately to gain posession of the ground. It is probably by such means that sugar pine is enabled to hold its position in the virgin forest.

When lumbering takes place these conditions are entirely changed. The forest is cut clear, and any sugar pine that secures a start is likely to suffer from drought and exposure, while yellow pine, which is more adapted to such conditions, gains posession of the ground.

In some localities where lumbering was first carried on, only the larger trees were taken, and thus only a partial clearance made. In such localities sugar pine had a better chance, and it is here that the best reproduction and second growth are found. The species never reproduces in pure stands and seldom forms as much as 25 per cent of the young growth, but it seems fair to predict that some of these stands when mature will contain as much as 50 per cent of sugar pine. Excellent examples of the above conditions are to be found in Butte, Tehama, and Eldorado counties.

The power of mature sugar pine to resist fire is sometimes underrated, for in this respect it far surpasses eastern white pine and compares favorably with most of its associates. In youth all suffer about equally from fire, and are either killed outright or injured sufficiently to fall a prey to fungous and insect attacks. Up to the time it is an inch in diameter, sugar pine is killed outright, and from that time until the pole stage is reached it is usually killed ultimately by anything but the lightest ground fires. Mature trees are very rarely killed by fire, unless it should get into the crown, and altho sugar pine has a much thinner bark than either yellow pine or Douglas spruce, it ranks well up in the list for fire resistance, the trees usually continuing to flourish without apparent permanent injury long after the butt has been badly burned.

In point of fire resistance the Sierra conifers rank as follows: yellow pine, Douglas spruce, sugar pine, incense cedar, white fir.

Windshake in the mature trees is not uncommon, but is usually confined to localities where the nature of the topography renders winds unusually severe or where for one reason or another the tree does not grow at its best.

Sugar pine is not particularly susceptible to fungous attacks, since trees that are badly fire scarred often live for a long period without suffering from fungous diseases. This is in part due to the six months' dry season, which is naturally inimical to fungous growth. In some localities, however, the mature trees suffer considerably from the attacks of "Trametes pini", which produces what is known as "red heart". It is claimed by some lumbermen that sugar pine growing on the Chico and Red Bluff ridges in Butte and Tehama counties is particularly bad in this respect, often 50 or 60 per cent of the mature sugar pine being infected more or less with red heart. It is significant in this case that rainfall in this region is as heavy as anywhere in the range of sugar pine in California. There are other fungous diseases to which the species is liable at different periods of its life, but the amount of injury from such causes is, on the whole, slight.

All the Sierra conifers are attacked by a parasite, a species of mistletoe (Arceuthobium occidentale), which grows on the limbs and small branches, drawing its food from the living cells of the tree. Sugar pine is probably freer from this parasite than any other species, and when mature trees are attacked early in life, however, are sometimes badly deformed, and young trees up to an inch or two in diameter are occasionally killed outright.

From insect injury sugar pine is again more immune than some of its associates. Attacks from insects that are capable of injuring healthy trees seem at present to be very local, and show little indication of spreading. Dr. A. D. Hopkins, in his report on his trip thru the West (Bulletin 21, Division of Entomology, Department of Agriculture), makes the following statement:

> A Dendroctonus allied to the one just mentioned (D. brevicomis), but evidently undescribed, was found to be a special and dangerous enemy of the sugar pine and mountain white pine (Pinus monticola), especially of the latter. It was frequently met with in the vicinity of Grants Pass, Oreg., in sugar pine, and was found abundant in the bark of dying and dead standing and felled trees in the vicinity of Sand Point and Kootenai, Idaho, where a large amount of timber had died, evidently as a result of its attack.*****
>
> It is undoubtedly capable of attacking and killing great quantities of white and sugar pine, but may possibly be prevented from doing so in the future, in all regions where extensive timber cutting is carried on, by its being attracted to the stumps, logs, and tops of trees felled for lumber and fuel.*****
>
> Another species at present recognized as Dendroctonus terebrans was commonly met with in the bark of living, dying, and dead standing trees and the stumps of recently felled Pinus ponderosa, P. lambertiana, P. monticola, P. murrayana, P. contorta, and P. radiata, in all of the localities where these species of pine grow.

The sugar pine has, of course, many other insect enemies, some of which attack leaves, roots, twigs, or seeds, but that described in Doctor Hopkin's report is probably the worst.

Besides the enemies of sugar pine already discust, there are numerous others that do it more or less hamm. Squirrels and ground mice destroy the seeds, and cattle and sheep sometimes destroy the young seedlings. In the case of cattle the injury is slight, as they eat only the smallest seedlings of not more than a year or two in age; that they do eat these is, however, an observed fact. Sheep grazing is much worse, as the bands of

sheep eat or destroy all the young reproduction in their path and leave the ground hard and trampled and in poor condition for reproduction.

White Fir (Abies concolor)

White fir occurs principally at the upper elevations within the merchantable timber belt and ranges from 500 to 1,500 feet higher. In the northern cross ranges and the northern Sierras it occurs between elevations of 3,500 and 7,500 feet. In the southern Sierras and the mountains of southern California it lies between 6,000 and 9,500 feet, descending to 5,000 feet occasionally on north slopes. It is everywhere an important tree, but its preference is for cool, moist situations and in these it is often predominant. At its best it grows in dense stands in which the soil is so shaded that underbrush is prevented from growing. It is tall and cylindrical, with long, narrow crown and clear length of from 40 to 60 feet. It reaches a height of 175 to 200 feet and a diameter of 3 to 6 feet. At high altitudes its average height is about eighty feet. Its rate of growth is fairly rapid, and it attains an age of about 300 years.

Altho it produces little seed and that only at intervals, and requires moist, cool situations in which to sprout, its reproduction is in general very good, owing to its ability to endure shade. In particularly favorable spots thruout the middle zone, but particularly in the northern Sierras, the proportion of white fir in the reproduction is often as large as 80 to 90 per cent. It is logged much less closely than sugar or yellow

pine and this circumstance also gives it the advantage. The young trees are extremely sensitive to the slightest fire, however, and promising reproduction is often destroyed by this means.

Inability to withstand scorching is also characteristic of the mature trees. The bark is very thin and being resinous besides, offers less than no protection to the tree. The leaves also are very inflammable, and crown fires in this species are not uncommon. The immediate results of fires in a white fir forest are bad enough, but the ultimate effects are worse yet. The white fir forest is usually extremely dense, containing little undergrowth. When it is destroyed by fire, however, it is usually seeded up promptly to chaparral. Provided a few seed trees escape, scattered seedlings may spring up amongst the chaparral, and they grow well beneath its shade. But the debris of the fallen fir trees is almost sure to invite other fires, and the chance of the seed trees ultimately surviving is very slight indeed. The reproduction they have secured is killed along with the chaparral, but the latter sprouts readily and the supply of fir seed being cut off the chaparral usually takes undisputed posession of the soil. This is the origin of many chaparral fields in the Sierras which are naturally prime forest land, but which now contain no trees, only acre after acre of chaparral of no value at all for timber, and immeasurably inferior to the fir forest as a conserver of water.

Abies venusta, a relative of the white fir, occurs only in the Santa Lucia Mountains, where it exhibits characteristics very similar to those of the latter.

Douglas Spruce (Pseudotsuga taxifolia)

The region of maximum development of Douglas spruce is north of California on the west slopes of the Cascades in Washington and Oregon. In California it is found thruout the redwood belt. On the Sierras it occurs as far south as the vicinity of Mount Whitney, and in the coast ranges to the Santa Lucia Mountains. It becomes of less and less importance from north to south and is finally replaced by its relative, the bigcone spruce (Pseudotsuga macrocarpa.) It prefers cool, moist situations. In the redwood belt it occurs especially on lower slopes, and on upper slopes as a rule only when they have north or east exposure.

In the Trinity, Scott, Siskiyou, and Yola Bola mountains, that is to say, in the northern cross ranges it occurs between elevations of 2,000 and 5,600 feet, sometimes reaching 6,000 feet; and it has much the same altitudinal limits thruout its Sierra range. Its best development on the Sierra occurs between 3,000 and 5,000 feet elevation. On the Santa Lucia Mountains it occurs between 2,000 and 3,000 feet. It is not found on the Warner Mountains or on the mountains of the desert.

In the redwood belt the Douglas spruce associates chiefly with redwood and tanbark oak, and along the eastern edge of the redwood belt occurs nearly pure. Thruout the Sierras its occurrence is scattered, and it rarely forms more than 5 per cent of the forest. It grows best on moist situations on well-drained, loamy soil.

The largest trees are between 150 and 180 feet high and 3 to 6 feet in diameter. Occasional specimens reach a height of

200 feet and a diameter of 8 feet, but these are exceptional. The tree does not prune itself easily. In close stands the boles may be clear for one-third to nearly one-half their length, but in open stands stout limbs are borne to within a short distance of the ground. Its age seldom exceeds 400 years.

In the northern Sierras reproduction is good, excellent sapling stands occurring on cut-over areas. Farther south it is much less satisfactory. Here Douglas spruce succeeds badly in competition with yellow pine and incense cedar, and seedlings are frequent only on the slopes of cnayons. The production of seed is also scant, and seed years occur at comparatively long intervals.

The seedlings are tolerant of shade in all situations, differing remarkably in this respect from the Puget Sound.

Seedlings of Douglas spruce are extremely sensitive to fire, and up to 30 years of age the lightest ground fire is apt to be fatal. The older trees are protected by thick, corky bark, and are less vulnerable.

In the redwood belt and in the northern Sierras Douglas spruce will probably form an important part of the future forest. In eastern Humboldt County it is already reclaiming large areas of open land where fires have been kept out; and in the northern Sierras a promising reproduction ordinatily follows logging. Southward, on the contraty, reproduction does not keep pace with cutting, and the probability is that the representation of this specie in the future forest will be small.

Incense Cedar (Libocedrus decurrens)

Incense cedar is widely distributed and abundant; and its silvical qualities are such as to affect in some degree the management of the more valuable species. Its range, within the State, includes that of yellow pine, but it extends somewhat higher on the slopes, ranging generally 500 to 1,000 feet above the latter. Thruout most of its range it is not at all fastidious, but grows in all conditions of soil and slope. In eastern Mendocino County, however, it is confined to the cooler, moister situations where it associates with sugar pine. Its preference for coolness and moisture is also shown by the fact that it does not occur on the east slope of the Sierras, and by the additional circumstance that its development is poorest on hot, dry slopes thruout its range.

It forms 1 to 2 per cent of the yellow pine forest in the Trinity Mountains, 2 to 7 per cent in the northern Sierras, and as much as 20 to 30 per cent southward. The stands of it are usually open, especially the older stands.

Altho it reaches a diameter of 7 feet the bole is very tapering and it seldom exceeds 100 feet in height. The crown is long and straggling, and as likely as not to be minus a top. The branches, too are brittle and often broken by the wind. The whole appearance of the mature tree suggests decrepitude and unsoundness, and one is not surprised to learn that the majority are shot thru with fungous disease. Its usual term of life is 100 to 200 years, altho occasional older trees may be found. It is not wind-firm, and suffers severely from fires. Its rate of growth is uneven but fairly rapid.

The incense cedar is an aggressive reproducer, approximating yellow pine in this respect. The seed is produced abundantly and regularly, and comes up readily especially in the drier situations. In the virgin forest seedlings of incense cedar share the openings with those of yellow pine, and are scattered also beneath the shade of the mother trees. The species is the most tolerant of shade of any in the yellow pine forest, and makes fairly rapid growth.

The species reaches maturity quickly, and dies at an earlier age than most of the other species with which it grows.

Bigtree (Sequoia washingtoniana)

The bigtree which is the largest, and in many ways the best remarkable tree in the State, has also the most limited distribution of any of importance. It occurs only on the west slope of the Sierras from the Middle Fork of the American line in Placer County, southward to the head of Deer Creek in Tulare County, a distance of about 260 miles. Within these limits it is by no means generally distributed but occurs in groves, about a dozen in number, which contain from six trees to several thousand. The southern groves are the largest. The groves have been named as follows, beginning at the north:

North Grove
North Calaveras Grove
South Calaveras Grove
Tuolumne Grove
Merced Grove
Mariposa Grove
Fresno Grove
Dinky Grove
Kings River Grove
Kaweah River Grove
Tule River Grove

Many of the individual trees have also been given names, particularly those in the groves most accessible to travelers.

The bigtree groves occur always at the upper levels of the middle belt of forest and range in elevation from 4,600 to 8,400 feet. The groves are never of pure growth, but almost invariably contain yellow pine, sugar pine, white fir, and incense cedar, among which the bigtrees are scattered singly or in small groups. The requirements of the bigtree as to soil and situation much resemble those of white fir and sugar pine and these two species are therefore, its most usual associates. The soil of the groves is a deep, rich, sandy loam, often fresh and containing considerable humus.

The general run of the larger trees have diameters of about 20 feet and heights of about 275 feet, tho these figures are often exceeded. The General Grant has a diameter of nearly 40 feet over all at the base, and heights of more than 350 feet have been recorded. The bole is rather tapering with an enormous swell at the root collar. The bark is very thick, and being without resin is an excellent protection against forest fires. In spite of this protection, however, most of the bigtrees are fire-scarred, some containing very large "goose pens", showing that constant successions of fires will in time destroy even the best protected tree.

Reproduction of the big tree varies greatly, but in general, conditions are unfavorable. Seed is borne abundantly but it does not sprout well on the litter which forms the forest

floor in most of the groves. Where the litter has been cleared off as by fire and the mineral soil is exposed, seedlings promptly take possession and grow rapidly.

Silver Fir (Abies magnifica)

The silver fir occurs on the northern cross ranges and on the Sierras thruout. In the former locality it is generally distributed above 5,000 feet, and on Mount Shasta it occurs between 5,500 and 8,000 feet, extending up as far as 8,900 feet on exceptional slopes. In the middle Sierras, about Lake Tahoe, its general range is about 500 feet higher, or between 6,000 and 8,500 feet, and toward its southern limits it ranges up to 10,500 feet.

It is not a timber line tree, but reaches its best development on the west slopes of the Sierras, near the lower levels of the upper belt on protected slopes with deep soil. Here it forms pure forests often of great density and considerable extent. In less favorable situations the fir is associated with lodgepole pine, Jeffrey pine, white pine, and black hemlock, the fir still forming the most important constituent of the forest. The mixt forests are more open than those of pure fir.

In the region of its best development it forms straight cylindrical boles, clear for 40 to 60 feet, and reaching a maximum diameter of 5 feet. Average dimensions are 2 to 3-1/2 feet diameter, and 100 to 140 feet height. Occasional trees attain a height of 175 feet. Above the optimum region, the trees are smaller, the boles very tapering, and the crown comparatively longer. A noticeable characteristic of this tree is

the curvature of the bole near the ground, caused by the weight of snow bending the seedlings. After the bole becomes stouter and stiffer it is able to support the snow without bending under it, and the tree grows straight henceforth; but the deformity acquired in its early years is permanent.

The silver fir produces seed abundantly, and at short intervals. The seedlings are not fastidious regarding their seedbed, bear shade well, and grow rapidly, forming thickets of exceeding density.

The young trees are particularly susceptible to fire having thin bark and inflammable foliage. Later in life the bark becomes thick and offers more resistance, and the leaves are too high up to be reached by a surface fire. But in early life the trees are entirely without protection and succumb easily.

Altho so easily destroyed, it reproduces aggressively and competes with the chaparral for growing space with great pertinacity; but when once a fire has occurred the litter is almost sure to invite a second, and the final destruction of seed trees usually leaves the chaparral in undisputed posession.

Lodgepole Pine (Pinus murrayana)

The lodgepole pine is generally distributed within the upper belt, occurring on the northern cross ranges, on both slopes of the Sierras, and on the summits of the mountains of southern California. On the northern cross ranges it is found between elevations of 4,000 and 8,000 feet. In the northern Sierras it ranges about 500 feet higher. In the vicinity of Lake Tahoe on the west slope of the Sierras it occurs between

6,000 and 9,000 feet, occasionally ranging both higher and lower. In the southern Sierras and the mountains of southern California its range is from the 9,000-foot contour up to timber line.

It grows well in all soils and in various situations within its range. It is particularly adapted to the heavy soils on the borders of meadows, and in these situations forms pure stands, sometimes of great density but usually open and park like. Elsewhere it is a constituent of the mixt forests, in which the silver fir predominates. It ranges generally to greater elevations than the latter. In the southern Sierras it occupies the canyons at the heads of the streams, with foxtail pine occurring on the slopes above it.

Even in the best situations the tree is usually short and of small diameter. It seldom exceeds 90 feet in height or 3-1/2 feet in thickness. Average diameters are from 1 to 2 feet. The clear bole is always short, and often entirely wanting. It is comparatively short-lived, the oldest tree seldom passing 150 years.

The reproduction of lodgepole, like that of California red fir, is prolific and aggressive. Any soil seems to be good enough for seedlings to take posession of, and having once sppouted they grow rapidly. They are quite tolerant of shade. Having thin bark, lodgepole pine is very susceptible to fire.

Silver Pine (Pinus monticola Dougl.)

Tho not a timberline tree this species is nevertheless confined to the higher elevations where it has a wide but interrupted range. In the northern Sierras it is found chiefly

between 7,000 and 8,000 feet. In the southern Sierras it is rarely found below 8,000, ranging from there up to 9,000 or even 10,000 feet. It is a typical constituent of the silver fir forest and occurs also with lodgepole pine. It grows on slopes and ridges and over the crests of high divides frequently in shallow and rocky soils. It occasionally reaches a height of 100 feet and a diameter of 3 feet but these dimensions are rare. It is usually short and conical with a long straggling crown. Seed is borne rather late in life and as a rule not abundantly. The seedlings are slow growing, making fair development in sufficient light.

Digger (Gray) Pine (Pinus sabiniana)

This is a characteristic tree of the foothills as far south as latitude 34° 30'. At the head of the Sacramento it ranges between 500 and 3,000 feet and in the Sierra Madres and Tehachapi goes up to 5,000 feet. It grows on the dry slopes on all soils and exposures, reaching its best development on the western slopes of the middle Sierras between 1,000 and 2,000 feet elevation. Here it occasionally attains a height of 80 feet and a diameter of 3 feet, altho elsewhere it rearly exceeds 40 feet height by 2 feet diameter.

Most conifers are excurrent, that is, the topmost bud is a direct continuation of the bole of the tree. This species differs from its class in branching more like hardwood. The branches are stout and the bole short, rendering the tree unsuitable for lumber. The crown is large, irregular, and very thin, plain evidence of its intolerance of shade, and the large

cones are plainly visible thru it. It is a prolific seeder, but reproduction, except at the upper limits of the zone, is usually poor. The seeds are edible and often used for food by the Indians.

It grows with a great variety of species and occasionally forms pure stands of limited extent. It does not occur south of Soledad Pass. It is not often cut for lumber but makes cordwood of fair quality.

Black Oak (Quercus californica)

The California black oak is found at middle elevations thruout the State. It never occurs pure, but forms an understory to the coniferous forests especially of yellow pine. In the northern and middle Sierras it ranges between 1,000 and 6,500 feet, ascending in the southern Sierras to 8,000 feet. It is especially partial to canyon sides and rocky ravines, and in general prefers moist soil, altho not particularly fastidious.

On the lower McCloud it forms an open woodland nearly pure. Elsewhere it is a part of the mixture, forming from 5 to 10 per cent of the stand, and occasionally 50 per cent on limited areas. These stands are always open and the trees are characteristically short-boled and limby. The black oak reaches a height of 40 to 50 feet and a diameter of 2 to 4 feet. It is comparatively short-lived for an oak, having an average age of 150 to 200 years.

It grows fairly rapidly in the sunlight, but will not endure shade. It bears seed in abundance, and reproduces persistently. Young seedlings sprout repeatedly after being burned,

and if fires do not follow each other with too great frequency, the sprouts serve as nurses for the more valuable species. They are, besides, comparatively fire resistant, even at an early age, and the old trees are rarely killed outright. They are hollow-butted, however, often with broken tops, and easily thrown by the wind.

Rock Oak (Quercus douglasii)

Blue, mountain, or rock oak (Quercus douglasii) has the same general distribution range as the gray pine but at slightly lower elevations. It ranges between 200 and 1,500 feet at the head of the Sacramento Valley and ascends to about 4,000 in the southern Sierras and the Sierra Madres. It is an important association of the gray pine, and together they form the largest part of the forest growth in this belt. In the deeper, richer soil of the slopes and valleys it occasionally reaches a height of 90 feet and a diameter of 4 feet. At elevations of 500 to 1,000 feet in the middle Sierras its ordinary size is 25 to 40 feet by 1 to 2 feet.

It is short-boled and large-crowned, and does not furnish saw timber, altho it is in demand for firewood. It often forms pure stands but is usually associated with the preceding and with Quercus lobata and others of less importance.

Its reproduction from seed is usually scanty, and altho it sprouts from the stump when young most of the trees cut are too old to reproduce satisfactorily in this way. It requires abundant sunlight.

Valley White Oak (Quercus lobata)

This species is distributed like the rock oak and digger pine, but at still lower elevations. In the deep soil of the upper Sacramento it reaches its best development, individual trees attaining a height of 100 feet and a diameter of from 6 to 8 feet, growing often in open groves without admixture of other species. Toward the north it ranges from the level of the valley up to 1,500 feet, mingling at its upper limits with rock oak and digger pine. Near the southern limits of its range just north of Soledad Pass it ascends to 4,500 feet.

It is the largest of the white oaks in California, but does not furnish saw timber. The bole is short and the crown heavy. It is used for firewood, but is inferior to the rock oak. It sprouts from the stump when young, but loses the power with age. Its seedling reproduction is generally scant.

Foxtail Pine (Pinus balfouriana)

Foxtail pine has very limited distribution being confined to higher elevations. In the northern cross ranges it occurs only on the Scott Mountains, China Mountain and Mount Eddy at elevations between 6,000 and 8,000 feet. In the Southern Sierras it occurs about the sources of Kings and Kern rivers in the Mount Whitney region; and upon the head waters of the middle and east fork of the Kaweah where it forms small irregular patches of nearly pure growth at altitudes above 9,500 feet.

Since it grows chiefly in exposed situations it is usually short stout boled and with a ragged crown. Seed is borne fairly plentifully but reproduction is scarce.

White-bark Pine (Pinus albicaulis)

This is a strictly timber line species. In the northern part of the State it occurs on Mount Shasta, Mount Eddy and a few other high peaks, at elevations above 750 feet; and in the Southern Sierras in several localities at 11,000 feet or above. It is a low stunted tree, becoming a mere shrub at timber line.

Limber Pine (Pinus flexilis James)

Limber pine occurs in a few localities in the Southern Sierras in open stunted stands at the highest elevations.

Black Hemlock (Tsuga mertensiana)

Black hemlock is a purely sub-Alpine tree occurring in the Northern Sierras above 6,000 feet and in the Southern Sierras above 10,000 feet.

It is usually scattered thru an open forest of silver fir, silver pine, foxtail pine, etc., tho it sometimes forms patches of pure forest of small extent. It is usually a small tree often stunted and misshapen. Reproduction is scant.

Western Juniper (Juniperus occidentalis)

Western juniper occurs thruout the Sierras at the highest altitudes and in rocky and exposed situations. It rarely becomes a large tree but is often a foot thru and 40 feet high. It seeds fairly abundantly and seedlings are not rare.

Pinon (P. monophylla)

This species occurs sparingly on west slops of Sierras but more abundantly on their eastern front. It is of small size never reaching merchantable dimensions. It does well in dry and exposed situations.

Table 11.--Growth in diameter and height of yellow pine

Age	Butte County		Madera County	
	Diameter breasthigh	Height	Diameter breasthigh	Height
Years	Inches	Feet	Inches	Feet
10	0.4	6	0.5	6
20	2.3	12	4.0	20
30	4.3	19	7.2	38
40	6.5	29	10.0	51
50	8.9	44	12.4	61
60	11.4	57	14.3	68
70	13.8	69	16.0	75
80	16.1	79	17.4	81
90	18.1	87	18.9	87
100	20.0	94	20.3	94
110	21.7	99	21.4	100
120	23.3	104	22.5	105
130	24.6	108	23.6	111
140	25.8	112	24.6	116
150	27.0	115	25.5	120
160	28.0	118	26.4	123
170	29.0	121	27.2	126
180	29.8	123	28.0	128
190	30.6	125	28.7	130
200	31.3	127	29.4	132

Table 12.--Growth in diameter and height of sugar pine

Age	Diameter breasthigh	Height
Years	Inches	Feet
10	0.7	7
20	2.5	15
30	4.1	22
40	5.8	29
50	7.8	39
60	9.9	49
70	12.2	60
80	14.4	70
90	16.5	81
100	18.7	92
110	20.9	103
120	23.0	113
130	24.9	122
140	26.6	128
150	28.2	134
160	29.3	138
170	30.4	140
180	31.4	142
190	32.0	144
200	32.4	144

Table 13.--Growth in diameter and height of white fir

Age	Diameter breasthigh	Height
Years	Inches	Feet
30	0.7	8
40	2.3	16
50	3.9	24
60	5.7	36
70	7.4	46
80	9.0	57
90	10.7	67
100	12.2	76
110	13.6	83
120	15.2	91
130	16.7	99
140	18.1	105
150	19.5	111
160	20.9	117
170	22.2	122
180	23.5	127
190	24.8	132
200	26.0	136

Table 14.--Volume table for yellow pine

Diameter breasthigh	Trees under 100 feet		Trees over 100 feet	
	Butte County	Madera County	Butte County	Madera County
Inches	Volume Bd.ft.	Volume Bd.ft.	Volume Bd.ft.	Volume Bd.ft.
11	..	..	..	..
12	..	27	..	..
13	20	42	..	..
14	45	61	..	..
15	75	86	..	..
16	105	116	..	..
17	150	153	230	..
18	200	197	285	..
19	260	248	345	..
20	325	318	405	449
21	400	378	470	519
22	470	451	540	597
23	540	531	615	685
24	615	612	700	778
25	690	693	790	883
26	770	772	900	995
27	850	849	1,020	1,119
28	930	924	1,150	1,253
29	1,010	..	1,290	1,398
30	1,090	..	1,460	1,543
31	1,170	..	1,635	1,711
32	1,250	..	1,810	1,897
33	..	..	1,990	..
34	..	..	2,170	..
35	..	..	2,350	..
36	..	..	2,520	..
37	..	..	2,710	..
38	..	..	2,890	..
39	..	..	3,070	..
40	..	..	3,240	..
41	..	..	3,425	..
42	..	..	3,605	..
43	..	..	3,800	..
44	..	..	3,990	..
45	..	..	4,170	..
46	..	..	4,350	..

Table 15.--Volume table for sugar pine

Diameter breasthigh	Trees under 100 feet	Trees over 100 feet	Diameter breasthigh	Trees over 100 feet
	Volume	Volume		Volume
Inches	Board feet	Board feet	Inches	Board feet
12	20	..	37	2,025
13	32	..	38	2,175
14	56	..	39	2,338
15	80	..	40	2,500
16	112	140	41	2,663
17	139	175	42	2,850
18	180	220	43	3,038
19	225	263	44	3,225
20	270	312	45	3,400
21	325	363	46	3,600
22	375	425	47	3,800
23	438	483	48	4,000
24	500	550	49	4,213
25	567	630	50	4,438
26	638	715	51	4,675
27	715	800	52	4,900
28	793	900	53	5,150
29	875	1,000	54	5,400
30	950	1,110	55	5,675
31	1,038	1,225	56	5,975
32	1,125	1,350	57	6,275
33	..	1,475	58	6,600
34	..	1,610	59	6,900
35	..	1,750	60	7,215
36	..	1,875		

Table 16.--Volume table for white fir

Diameter breasthigh	Volume
Inches	Board feet
12	55
13	75
14	105
15	140
16	185
17	240
18	295
19	360
20	430
21	510
22	600
23	695
24	795
25	905
26	1,025
27	1,160
28	1,300
29	1,455
30	1,610
31	1,770
32	1,935
33	2,100
34	2,275
35	2,440
36	2,620
37	2,790
38	2,970
39	3,155
40	3,340
41	3,520
42	3,700
43	3,885
44	4,065
45	4,260
46	4,440
47	4,630
48	4,815
49	5,005
50	5,195

Table 17.--Comparative heights of sugar pine, yellow pine, and white fir

Diameter breast-high	Sugar pine	Yellow pine		White fir
	Butte County	Madera County	Butte County	Siskiyou County
	Height	Height	Height	Height
Inches	Feet	Feet	Feet	Feet
1	8	8	7	9
2	13	11	10	14
3	17	16	14	19
4	21	20	17	25
5	26	25	22	31
6	30	31	27	38
7	35	37	33	44
8	40	42	39	50
9	44	47	45	57
10	49	51	50	63
11	54	55	56	69
12	59	59	61	75
13	64	63	65	80
14	68	67	70	85
15	73	71	74	90
16	78	75	79	95
17	83	79	83	100
18	88	83	86	105
19	93	88	90	109
20	96	93	94	113
21	103	98	97	118
22	108	103	100	122
23	113	108	103	126
24	118	113	106	129
25	122	118	109	133
26	126	122	113	136
27	130	125	116	139
28	134	128	118	142
29	137	131	121	145
30	140	134	124	148
31	142	136	126	151
32	144	138	129	154
33	145	140	131	156
34	146	142	134	158
35	147	143	136	161
36	148	145	139	163
37	150	146	141	165
38	151	147	144	167
39	152	148	146	169
40	152	149	148	171

Forest Fire

The forests of the Sierras would be more valuable and more extensive to-day if fire had not run thru them for so many years. Individual trees have been killed, the density lessened, natural extension checked, chapparral areas increased, and watershed cover injured. In most of the forests of the northeastern United States the fire damage followed lumbering, and the original timber was the result of competing productive forces. In California, where climate and soil favored optimum growth, the destructive element of fire was continually present. The forests, despite this factor, are almost unsurpassed, but they would have undoubtedly been much finer had the fire element been absent.

Most of the early fires were set by Indians to drive out game. Following the Indians came herdsmen who fired the country to improve grazing. Hunters and prospectors were also responsible for many fires.

Conditions have changed greatly in the past fifteen years, and at the present time careless campers, and logging locomotives and donkey engines start most of the fires. The Indian danger is past, save in San Joaquin County where drunken Mono and half-breed Indians often unintentionally start destructive fires. Less common causes of fire are brush burning, wood blasting, carelessness with matches, etc., mentioned under the heading of southern California.

A comparatively new source of danger comes from the development of the lumber industry. This brings an additional number of men into the mountains, and the accumulation of debris

after logging add greatly to the fire danger. Logging locomotives and donkey engines since they burn wood, very frequently throw sparks into the inflammable brush and litter.

The Southern Pacific Railroad is the only thru line traversing the forest regions. Since oil is used exclusively for fuel, the danger from sparks is minimized. On the heavy grades, however, the adjacent brush is occasionally ignited.

Lightning occupies a secondary place in the list of fire causes. Dead stubs are sometimes set on fire, and the flames may spread. The worst feature is that such fires start in isolated, unexpected places, but on the other hand showers frequently follow and extinguish the flames.

Character

In virgin timber ground fires are the rule, and it is seldom the flames reach up into the foliage of large trees, even in stands of fir. Where there is little undergrowth, such fires are easily controlled, since they have only the litter of the forest floor for fuel. They often burn deep into the humus, however, and may smoulder for days. Wherever dense undergrowth exists, as along the lower edge of the timber belt, the fires are naturally more severe, and more difficult to control, and individual trees and clumps are occasionally killed.

The erratic behavior of a fire in the unlumbered forest is very noticeable. In one spot it may burn with severity enough to kill or injure good-sized trees; again, for long distances it will run so lightly over the forest floor as to little more than black it; while here and there it will run out in long irregular tongues with large unburned areas between.

On cut-over land the fires assume an entirely different character. Three conditions a re created, each favorable to fire. (1) The accumulations of unburned, undecayed slash and debris. (2) The brush which has replaced the timber on the older cut-over areas. (3) The dense thickets of coniferous reproductions which have escaped destruction.

Many factors such as season of the year, wind, condition of the slash, and topography influence the character of fires on cut-over land. As a rule, however, they are very severe, and destroy all reproduction and eventually, if repeated, all seed trees. Where brush has taken posession, as is often the case, the chaparral fires are brought up into the timber belt.

In the lower foothills the brush is so open that the fires are not violent, save in individual bushes or clumps of brush. The dry grass, however, carries the flames readily, and a rather fast running fire, severe in places, is the result. In the upper foothills where the brush is dense, and in chaparral generally, a fierce fire, difficult to control, is the rule when wind and weather are favorable. (Photo. 54550).

Effects

The ordinary ground fire seldom kills mature trees, unless they are surrounded by dense brush or slash, and the damage, from a lumberman's viewpoint, is not great. There is, however, an appreciable financial loss from the burning out of the base of the trunks by repeated fires; while the destruction of young growth by reversion of forest land to chaparral is clearly a public calamity.

Practically every mature tree shows marks of fire either by the charred bark or burned-out base. Many of the largest sugar and yellow pine have cavities at the base large enough to shelter a man, (photo. 54561) and every fire burns in a little deeper. Some of these trees eventually burn thru or are blown down, thus reducing the density of the forest; while the repeated destruction of young growth prevents a return to normal density.

Figures secured in the logging camps of the Sierra Lumber Company in Tehama County, show that the "long butting" necessitated by the burned-out cavities in the butt logs amounts to 4-1/2 per cent of the total cut. This does not include the waste in high stumps where the cut is made above the cavity, nor allow for the inferior lumber near the burns, where the heat has hardened the pitch. In the aggregate the loss would often be 10 per cent; taking, however, the very conservative figure of 5 per cent, and the loss to a concern cutting 30,000,000 feet a year amounts to 1,500,000 feet. Despite this, ground fires are said to work little or no damage to large trees.

It is difficult to say what species of pine suffers most, as the damage varies with localities. The Douglas spruce (Pseudotsuga taxifolia) is slightly more resistant to fire than pine, and burns grow over more rapidly if not too large. The fir suffers most, as the foliage is very inflammable, and the wood, when exposed by fire, decays rapidly. The bark, however, is thick and fire-resisting, but once broken or burned thru the tree falls prey to wind or subsequent fires. The bigtrees, (Sequoia washingtonia) altho badly scarred have rarely been killed or their vitality greatly reduced by fire. In all cases the bark burns

very reluctantly, but despite this, repeated fires have burned large cavities into the base of most of the large trees. The only fire-killed bigtrees were a small group on Redwood Mountain in Tuolumne County (photo. 54571).

The reversion of timber land to chaparral thru repeated fires which kill the reproduction and eventually the seed trees, is one of the serious problems in the commercial forests. The chaparral is able to endure these repeated fires since it sprouts from the root, and has obtained possession of enormous areas once densely forested. One of the best examples is seen around the base of Mt. Shasta. Along the lower timber belt Ceanothus cuneatus, Prunus subcordata, Arctostaphylos glauca, Arctostaphylos viscida, Quercus wislizenii, Cercocarpus parrifolius, and Ribes speciosum, are the principal species replacing the forest. At the higher elevations the pernicious Ceanothus cordulatus is taking possession where fire or lumbering has removed the forest. Abies concolor is about the only species which readily works back into the chaparral when fires are prevented. (photos. 54617 and 54618). The chaparral persists in spite of fire and takes possession of open areas rapidly, but is at times reduced in density, and changed in composition by frequent burning.

The common chaparral species are susceptible to fire in varying degrees. In the foothills Ceanothus cuneatus, and on the higher elevations Ceanothus cordulatus burn most readily. With both this is not because the foliage is particularly inflammable, but because they grow in dense stands and contain much dead material, such as twigs, leaves, and branches. Umbellularia californica burns fiercely on account of the oily nature of its thick

leaves. The species which burns most reluctantly is Aesculus californica, altho all species of Prunus are nearly as fire resistant. The several species of Arctostaphylos, Cercocarpus, and Quercus burn indifferently, not carrying or holding flame, but burning freely where sufficient heat is generated by other fuel.

All the chaparral species sprout readily after fire save Ceanothus cuneatus, and some of the larger forms of manzanita.

Lumbering

The species lumbered within the Sierra region are six in number, namely, sugar pine, yellow (white) pine, Douglas spruce (red fir), incense cedar, white fir and bigtree. The two first are of prime importance, the others being rarely logged except in conjunction with them. Together they constitute 80 per cent of the cut in this region, yellow pine forming about 60 per cent and sugar pine 20 per cent. Douglas spruce and white fir make up the bulk of the remainder, bigtree being extremely limited in distribution, and cedar being cut as a rule only for special purposes and more or less local use. All of these species except Douglas spruce, attain their best development and their greatest commercial significance, within the state of California.

Jeffrey pine need not be distinguished from yellow pine as regards commercial qualities.

Wood

The wood of yellow pine varies as greatly as do the silvical characteristics of the tree. In one locality alone four kinds of trees are distinguished, the classification based largely

on the character of the wood. The wood is rather heavy as compared with that of sugar pine, is hard and strong, sometimes brittle, and very resinous. The heartwood is reddish brown, and the sapwood yellowish white and often very thick. The sapwood from certain trees when finished, has a beautiful satiny luster, is light and easily worked, and is equal to sugar pine for finishing purposes.

Yellow pine has a specific gravity, when dry, of 0.4715, and rough dry lumber weighs about 2.7 pounds per board foot. It is thus considerably heavier than sugar pine and is proportionately stronger.

Yellow pine has a great variety of uses, especially where a strong, durable wood is desired. It is extensively used for building materials, such as scantling, beams, flooring, ceiling, etc., railroad ties, door stock, and matches. Small trees 6 inches, 8 inches, and 10 inches in diameter are extensively used in some localities for mine props; in fact the use of yellow pine for mining timber was one of its earliest uses.

The wood of sugar pine is soft, straight-grained and easily worked. It is very resinous and the resin ducts are large and conspicuous. The heartwood is light brown in color, while the sapwood is yellowish white. When finished the wood has a satiny luster that renders it excellent for interior finishing.

The specific gravity of the dry lumber is 0.3684; and rough dry lumber averages about 2.5 pounds to the board foot.

In contact with the soil, sugar pine shows moderately durable qualities, altho this might prove less apparent in a climate not so dry as that of California. In brief, sugar pine

closely resembles the eastern white pine in its physical characteristics altho it is generally considered a trifle more brittle than the latter, and its large, conspicuous, resin ducts are somewhat of a detraction.

Sugar pine lumber has an almost endless variety of uses. It is used extensively for doors, blinds, sashes, and interior finish. In pattern work sugar pine is largely replacing white pine, as it is cheaper and its softness and straight grain render it an excellent substitute. Its freedom from odor or taste causes the wood to be much used in the manufacture of druggists' drawers. Other common uses are for oars, moldings, ship work, chain boards, bakery work, cooperage, and wooden ware - in short for almost any purpose for which white pine is used. The poorest grades are used extensively for boxes, especially fruit boxes, and for drying-tray slats.

The wood is still used for making shakes (a hewed shingle 36 inches by 6 inches), and its straight grain and the ease with which it splits have made this, in the past, almost the first use for which the tree was sought. Logs, too knotty to cut into uppers, but otherwise sound and straight-grained, are sometimes turned into bolts for match work.

Douglas spruce, called also red fir, Douglas fir, and Oregon pine, is the only one of the Sierra species that occurs also in the redwood belt, and it forms part of the output in both localities. About 40 per cent of the Douglas spruce cut in California comes from the redwood belt and the remainder from the Sierra region.

In California the tree deteriorates steadily from north to south; practically all the Douglas spruce cut in the Sierras comes from north of Eldorado County.

The wood is heavy, strong and very durable. It is harder than the pines and not so easily worked. Its great strength gives it a value for bridge timbers and heavy construction work and its durability suggests its use for railroad ties, mine timbers and in other exposed situations. Very little Douglas spruce lumber is shipped, most being consumed locally.

The Sierra Douglas spruce is generally sound but is low in its content of clear lumber. The bole is comparatively short and tapering and ill-pruned. The lumber is consequently knotty.

Incense cedar has extremely valuable qualities but is not considered highly by Sierra lumbermen. It has an extremely rapid taper, and is almost invariably unsound, cavities filled with brittle brownish material occurring thruout the heartwood. The wood between the cavities is usually sound, and except in so far as the unsoundness affects the strength or appearance of the lumber, it is not objectionable for the rot does not continue after the tree is cut. In fact incense cedar is one of the most durable of all trees either in the ground or when exposed to the weather.

The wood is light, soft, and straight-grained. It is chiefly used for fencing and poles, somewhat also for sills, etc. It is not shipped to any extent.

Bigtree has such a limited occurrence that it does not figure largely in the total cut. In the region of its best

growth, however, it is abundant, and it furnishes a considerable proportion of the output of several south Sierra mills.

Its wood resembles that of the Coast redwood and has much the same qualities as that of incense cedar. It is light, soft, even-grained, and very durable. It is used for shingles and pencil stock which are exported, and for posts, vine props, etc. which are used locally.

White fir is the most recent of the Sierra species to become merchantable, and its standing on the market is even now very insecure. The reason is apparent: its wood is similar to that of the pines but far inferior, and it posesses no special qualities (except one) as durability or strength, to recommend it. Hitherto it has had no field outside of that covered by sugar and yellow pine in which it could not compete.

It is light, brittle, soft, yet not easily worked; warps considerably, splits easily, does not hold walls well, decays quickly when exposed, and is often wind-shaken. It is odorless and tasteless and therefore useful for boxes, woodenware, etc., and has had some use as door stock, in which it proved fairly serviceable. Its principal future use will, however, be in the manufacture of paper. It is soft, white, and has a fairly long fibre, three qualities of a paper wood.

The Lumber Industry

Lumbering in the Sierra timber belt began early in the fifties with the hewing of logs and splitting of sugar pine shakes by the settlers and the cutting of mining timbers along the foothills. Water-power mills, running "up and down", or small

circular saws, were soon introduced and began cutting small quantities of lumber for local use. This early cutting was insignificant, the increasing and extending rapidly to keep pace with the growth in population and the development of mining and farming towns.

. Commercial lumbering to supply the general market necessarily awaited the construction of the transcontinental lines and the extension of the California roads to points from which the timber would be accessible. It began 30 years ago along the route of the Southern Pacific across the Sierras, but in the region as a whole has been confined to the last 15 years.

Within that period, the industry has tended steadily to centralize in large, well-capitalized concerns. The country in the main is rough and inaccessible. The timber lies at long distances, in many cases 40 to 60 miles, from the main railroad lines. Natural means of transportation, as drivable streams, are lacking. Under these conditions a large investment is required at the outset to develop cheap transportation; and to realize upon such an investment, the whole operation must be conducted upon a proportionately large scale. This requires a large, well-equipped plant, with the most advanced methods of logging and manufacture.

In the typical operation in this timber belt, therefore, an initial expenditure of from 50 to 300 thousand dollars is required to connect the mill-site back in the timber with the main line shipping point. In northern California where the country is more broken and easier routes can be found, a standard or narrow gage logging railroad is usually built. In the central and southern Sierras, where the steep western slopes of the range are

much less cut up, a box or V-shaped flume is usually constructed from the mountain mill to the valley railroad, in some instances covering a distance of 65 miles and dropping 5,500 feet in elevation.

The mill usually represents an investment of $60,000 to $100,000. It is almost invariably of the double band saw type, frequently with one or more re-saws or gang saws, and is always equipped with gang edgers and trimmers. It cuts from 90 to 150 thousand feet of lumber in ten hours run. A short logging railroad, extended frequently for 10 or 15 miles as the operation progresses, taps the standing timber and brings the logs from the woods in to the mill-pond.

Logging

The logging in the timber itself, is in many respects the most critical part of the whole operation. In this mountain region, the logging season is usually limited to six months and the work must be conducted on a very large scale to secure a sufficient run of logs to make the year's operation successful. Steam logging, by donkey engine and cable, is the method usually employed. Crews of fallers go thru the timber first, dropping the trees, clearing off limbs, and "bucking" the trunk into log lengths. Light donkey engines, carrying 1,000 feet of 7/8-inch cable, snake the logs over the unbroken ground to the yards at the end of the chutes. The latter are built in trough fashion by spiking two logs side by side on short stringers and beveling the inner surfaces. At the yards, the logs are chained together in strings and hauled in over the greased chutes to the landings on the railroad. Powerful "bull" donkeys, carrying three to

four thousand feet of heavy cable, are used for this purpose. In many cases, as the chutes extend out into the timber, two or three donkey engines are required, one hauling a string of logs the full length of its cable and then the next taking it in two. The chutes occasionally cross ridges of considerable height, one donkey engine serving as a hoist at the summit to take the logs up the incline.

Cost

An average operation requires from 15 to 20 donkey engines, equipped with cables and costing from $2,500 to $3,000, to the machine. With the other logging equipment necessary and the construction and rolling stock for the railroad, an investment of fully $100,000 in addition to the cost of the sawmill is required before actual operations can begin.

The cost of logging and transportation of the logs from the woods to the mill varies from $3 to $7 per thousand, the average under typical conditions being about $5. The cost of milling averages about $2. Fifty cents must be added every time the lumber is handled. Transportation from the mill to the shipping point varies from $1.50 to nearly $10 with an average range of $2 to $4.50.

Adding, finally, the cost of seasoning and making allowance for stumpage, taxes, insurances, interest and depreciation it costs the Sierra lumbermen about $15.50 per thousand feet to put his product on the market. Since the average selling price f. o. b. of the mill-run is only about $17.50 per thousand, the margin of profit is small.

Output

Comparison of the statistics of the lumber cut for the years 1900 and 1905 is interesting as showing the growth of the lumbering industry in the Sierra region.

The total cut for the State, for 1900 was, according to the twelfth census:

Yellow pine	285,306,000
Sugar pine	52,308,000
Redwood	360,167,000
Other species	37,071,000
	734,232,000

In 1905 the cut of the same species was as follows:

Yellow pine	363,932,000
Sugar pine	120,002,000
Redwood	405,919,000
Other species	171,754,000
	1,061,607,000

The total represents an increase of nearly 45 per cent in the lumber industry as a whole. Redwood has increased 13 per cent; yellow pine, 28 per cent; and sugar pine, 130 per cent since 1900.

The cut in the yellow pine region as distinguished from the redwood belt was, in 1905, 604,929,000 feet, comprising, besides the yellow and sugar pine given above, 54,812,000 feet of Douglas spruce; 51,630,000 feet of white fir, and the balance incense cedar and bigtree. An additional 46 million feet of Douglas spruce was cut in the redwood belt.

Dividing the district at the Amador-Eldorado line, the cut to the northward was: yellow pine 307,851,000, or 84.6 per cent of the yellow pine cut; sugar pine 56,242,000, or 46.8 per cent of the sugar pine cut; Douglas spruce, practically all; white fir 20,968,000, or 40.6 per cent of the white fir cut. The heaviest cut of yellow pine is in Siskiyou County with 134,435,000 feet. Tuolumne, Fresno, and Madera are the largest sugar pine producing counties.

Yellow and sugar pine together form very nearly one-half the output of the State, and if the amount of other species cut by the sugar and yellow pine mills is considered, they form more than half the lumber industry of the State. This division of the industry, namely, redwood on one hand and sugar and yellow pine on the other, is a geographical one and extends to the mills and market as well. From a market or commercial standpoint sugar pine and yellow pine may therefore be considered by themselves.

Of the total cut of yellow and sugar pine, about 55 per cent is cut by 8 mills, while the bulk of the remainder is cut by 30 or 40 smaller mills. The total number of mills cutting these species is about 214. Of all the sugar pine cut in the State, over 70 per cent is cut by 5 companies, which cut sugar pine chiefly, and the rest of the cut is distributed among 15 or more companies.

The most important factor of the sugar and yellow pine market is the competition of Washington and Oregon lumber, which has practically driven these two woods out of the general California market and entirely out of the San Francisco market.

This is due to the cheapness of Oregon and Washington lumber, and to the fact that the San Francisco market can be reached at a smaller cost for transportation by the Oregon and Washington lumbermen than it can by the California sugar and yellow pine producers. For example, the water freight rate per thousand feet from Portland to San Francisco is but $3.25, while the average rate per thousand for rail shipments from the San Joaquin and Sacramento valleys is $5. The extent of the competition may be realized when it is known that 700,000,000 feet were shipped into California last year, and altho a large part was undoubtedly reshipped, a good proportion remained in the State. To meet this competition and to open up markets outside the State, the sugar pine and yellow pine producers have organized what is known as the California Sugar and White Pine Agency. This agency to some extent regulates the output and prices, but actually handles but 25 per cent of the total output, and this 35 per cent is wholly made up of the upper grades. These grades are for the most part marketed outside the State, the sugar pine going largely to the eastern seaboard, where it is sold for from $50 to $65 per thousand and competes with corresponding grades of eastern white pine. In fact, there is at present very little trouble in marketing the better grades of this timber. Some sugar pine also is distributed thru the Middle West, where it goes to supply sash, door, and blind factories, and the like. Very little sugar pine goes abroad.

The yellow pine competes to some extent in the Los Angeles market, but it has rather lost ground to Oregon fir in the last few years. The principal market lies thruout the Middle

West, where it competes successfully with southern pines. Last year about 5,000,000 feet of the upper grades were exported. Of this 4,000,000 feet went to Australia and New Zealand, while the remainder went to Europe by way of Galveston, principally to Liverpool, Belfast, and Glasgow.

It is in the marketing of the lower grades, however, that the sugar and "white" pine producer meets the greatest difficulty. The freight rates - 75 cents per hundred pounds to the Atlantic seaboard and 60 cents to Chicago - effectually closes the eastern market to these grades of lumber. Forced to look for his market nearer home, the producer has developed the box industry and his own local market. Considering that approximately 50 to 60 per cent of the sugar and yellow pine cut is in the lower grade - that is, commons - and that the bulk of this is manufactured into boxes, the magnitude of the industry may be appreciated. Most of the sugar and yellow pine companies now operate their own box factories or else supply a box factory in their immediate neighborhood. They thus supply the fruit growers of southern California with fruit boxes, but even here they meet with competition from the yellow pine lumbermen of New Mexico and Arizona, whom thru lower railroad rates westward to stimulate the haul, can often put their boxes into southern California as cheaply as or more cheaply than the California lumbermen themselves. Thus, altho the market for sugar and "white" pine is good, it is far from what it might be. Improved market conditions are largely dependent upon the state of the industry in Washington and Oregon, and such periods of overproduction in the northwest as have occurred in the past two or three years have

necessarily been felt by the sugar and yellow pine producers. As conditions improve, however, and the eastern and foreign markets reach their full development, prices will undoubtedly rise.

The agency grades pine as follows: No. 1, 2, and 3 clear; 1, 2, and 3 siding; 1, and 2 shop, and common or box lumber. All except the last named are classed as uppers. No. 2 shop, however, is sometimes classed as uppers and sometimes as common, and it is largely this grade which is used in the sash, door, and blind factories.

Uppers of sugar and "white" pine range from $30 to $40 up, f. o. b. the cars in California. Special grades, such as extra thick, etc., bring as high as $60 or $65 f. o. b. One large company lays down the best grade sugar pine, ordinary dimensions, at $55 per M in New York. No. 2 shop brings about $16 f. o. b. In spite of this, however, the mill run averages about $17 per thousand, f. o. b. at the point of shipment.

Effect of Lumbering and Condition of Cut-over Land

Logging in this region as a rule, is very destructive. Trees of any merchantable value are usually cut to a diameter of 19 or 20 inches. In building chutes, moving donkey engines from set to set, slinging the heavy block and tackle rigging for cables, and snaking logs to the yards along the chute, the little remaining growth is largely destroyed. Fires are often started by donkey and railroad engines, and feeding upon the masses of inflammable limbs and tops, clear the ground of young growth of every description. It is here that the forester raises the question: is it necessary or wise for the average lumberman to

leave his land in a semi-barren, unproductive condition, of little value either to himself or to the State?

The following discussion is an attempt to answer this question from the lumberman's own point of view.

Practical Forestry

The forests of the Sierras are, without question one of the State's greatest resources. They give direct employment to thousands of men, and there is scarcely an industry or an individual in the State but shares in the indirect benefits they bestow. They represent an enormous capital which pays yearly interest in the shape of manufactured lumber to the value of 10 million dollars, and under wise and conservative management are capable of continuing to do so indefinitely. But besides furnishing lumber, they furnish water and it is for this reason that they are to be valued more highly than the forests of the redwood belt. The latter forests, tho extremely valuable as lumber producers, protect the heads of few important streams, while the Sierra forests act as regulators to the flow of a dozen rivers of the first importance and innumerable small streams. The future of the great interior valley and to a large degree, the welfare of the State as a whole, depends entirely on the preservation of these forests which are now being lumbered at the rate of more than 500 million board feet annually.

In order to insure a permanent supply of wood and water, the Government has reserved nearly 15 million acres in northern California on which the forests are managed with a view

to permanence. All the forest resources of these areas are utilized, but economically and with an eye to the future.

On the other hand a large proportion of the merchantable timber of the State is owned privately by men who naturally try to make their exploitation of it the source of the greatest profit to themselves.

The effects of ordinary methods of exploitation by lumbermen have already been discussed. It remains to point out practicable improvements in method by which the producing power of the forest may be maintained and the watershed cover preserved.

Forestry on the National Forest Reserves

The National Government, owning 9,500,000 acres of forest reserves and withdrawals in the sugar and yellow pine belt, is the largest holder of timberland and was naturally the first to adopt a definite policy of conservative management. The policy of the Government in the administration of its reserves, may be expressed in the single word, "permanence". Its aim is to make the forests and timber supply of the reserves, like their stock range, of continuous and permanent usefulness to the people of the State.

The first point in carrying out this policy is the protection of all reserve land, both virgin and cut-over, from forest fires. A constant patrol is maintained during the dry season. A system of trails and telephone lines is being constructed on each reserve, to secure better communication and greater rapidity in reaching fires. Stations for storing fire-fighting

tools are built at strategic points. In some instances, special fire breaks are being constructed to serve as vantage points in fighting fire. Most important of all is the strict adherence of the Forest Service to the policy of putting out every fire that gets started, by hard, continuous fighting and employing extra help if needed.

These methods, with the backing of statutory provisions, are steadily making the protection of the forest reserves more complete and efficient.

On the reserves which are wholly or partially included in this timber belt, there are 141 rangers and guards patroling a total area of 13,710,379 acres, or an average area of 97,237 acres per man. The total cost of administration, of which protection is but a single item, is 8-6/10 mills per acre.

The second important feature of the Government's reserve policy is conservative cutting. There is no purpose to withhold reserve timber from use. On the contrary, all mature timber on the forest reserves is for sale. No cutting is allowed, however, unless a good second growth after logging is assured. As far as possible, the basis for the new stand of timber is left on the ground in the form of young, thrifty trees. The aim in all reserve cutting is really threefold:

1. To remove and sell the mature timber.

2. To improve the quality of the stand by thinning out less desirable species.

3. To leave the ground in such condition that a good second growth will follow logging.

In all cutting upon the reserves in the sugar and yellow pine belt, the forest officers mark the trees which are to be taken. All fully matured and overripe trees and trees which are unsound from fire scarred butts, dead crowns, or insects, are marked for cutting; while thrifty trees which will grow and produce seed for another fifty or one hundred years are left if of valuable commercial species. In northern California Douglas spruce is classed as a valuable tree, and hence is cut lightly together with sugar and yellow pine, while the less desirable white fir and cedar are cut as closely as they can be taken.

Care is exercised in all marking that the ground will receive an abundance of the right kind of seed after cutting. If the thrifty trees alone will not furnish this, additional seed trees are selected from the mature timber which is most sound and best able to stand. As far as practicable, at least three seed bearers are left to the acre on logged-over land.

A few other simple points in practical forestry are followed in marking. It is required that skids and other small poles used in logging, be cut from young white fir. The fir taken for this purpose are cut, if possible, from thickets where they are overtopping and crowding out sugar pine or other valuable species. Thrifty trees are thinned where crowded in dense bunches, with the aim always to leave the most vigorous and promising, and the ones best placed for the distribution of seed. At the same time, if any choice is possible, the remaining trees are left in groups rather than scattered singly for greater protection against windthrow. Thickets of promising reproduction of valuable species are favored as far as possible in marking. Trees

which would smash them up badly in falling are left for seed, if not too large and mature. Other trees around the edges of such thickets, which can be felled safely, are marked so as to give the young growth more light and space and room for extension.

In all cutting upon forest reserves, the Government insists upon three things which, at least as regards the last two, distinguish its logging from that upon private lands:

1. The clean use of all merchantable timber. No waste is allowed in stumps or tops. No attempt is made to enforce hard and fast rules or specified limits, the requirement being simply that everything merchantable shall be taken. The forest officers, for example, insist that smooth, even-butted trees be cut within 18 inches of the ground; as low as they can be handled. Partially unsound trees must be cut if they contain one or two merchantable logs, and all dead trees sound enough for lumber. Long butting of partially-burned trunks is not allowed. Young trees with small crown limbs are used up to a diameter of 10 or 12 inches in the tops; large, heavy-crowned trees, as high as merchantable logs can be cut in the judgment of the forest officers.

2. The preservation from injury of unmarked trees and young growth in handling, rigging for donkey engines, and felling and logging marked timber. Much injury of this character is unavoidable. At the same time a great deal can be prevented by reasonable care. The forest officers require that rigging for donkey engines be slung as far as possible upon marked trees or stumps to prevent the notching or girdling of young trees or

which are to be left. Similar care is enforced in dropping trees and snaking logs so as to damage as little as possible the young growth upon which we rely for the next stand of timber.

5. Cleaning up and removing the slash after logging. This is required principally as a safeguard against forest fires and also to clear and expose the soil for better seed germination. Various methods of piling slash have been tested in the past, entailing an expense in specific cases of from 30 to 88 cents per thousand feet for the actual stand of timber cut upon the area. The method now required upon all of the reserves thruout this timber belt is to lop the branches from the rejected tops and pile them compactly in the openings, together with all limbs cut from the merchantable portion of the tree. These piles are burned by the Rangers after the first fall rains have dampened the ground and made it easy to control the fires. The naked tops are left where they lie, forming in themselves no serious menace to the forest.

The lopping and piling of the limbs costs, in the densely-wooded Sierra region, approximately 35 cents per thousand feet. This is invariably borne by the purchaser. An additional 10 or 12 cents, borne by the Government, is required to burn the piles.

In addition to the cost of piling slash, the reserve regulations make logging upon the Government land slightly more expensive than upon private land. This is due to the precautions required to avoid all injury possible to unmarked trees and young growth, and to the fact that a small portion of the merchantable timber is left uncut, tending to increase slightly the average

cost of the operation. In the judgment of experienced lumbermen who have logged reserve timber, the increased cost due to the last two features is inappreciable. Taking all of the reserve regulations together, including slash piling, the cost of logging is not more than 50 cents greater per thousand feet than upon private lands under the usual methods of operation.

At least 20 timber sales of fair size are now under way upon the reserves, included in the sugar and yellow pine belt. This is sufficient evidence that the reserve regulations governing logging are reasonable and practical from the lumberman's standpoint.

The Federal Government, the largest owner of timberland in this region, has thus adopted a definite policy of protection, conservative cutting, and simple logging restrictions. Its purpose is to keep its land permanently timber producing.

Forestry and the Lumberman

Fire protection.--In any system of conservative management of Sierra timberlands the first point is protection against fire, especially of cut-over and second-growth lands. Hitherto a lack of method has characterized the lumberman's management of the fire question. No systematic effort is made to prevent or control fires, and few concerns even use spark arresters on their engines. The result is that fires are frequent. When a dangerous fire starts, all hands are called out to fight it, and the mills are shut down if it assumes large proportions. Interest then wanes until the next fire starts. Despite this, many of the largest concerns say that fires are not troublesome, and do

only a few hundred dollars damage annually. The Madera Sugar Pine Company, Sierra Lumber Company, and McCloud River Lumber Company admit that fires are expensive and give much trouble. Fire fighting cost the first named company $1,200 in three years, not including the timber and machinery destroyed.

Fire control is an individual problem with each lumber company, but there is no reason why it can not be effected economically, if organized as sanely as the other branches of the business. To demonstrate that a system of fire protection is practicable, initial experimental work of this kind was inaugurated on the lands of the McCloud River Lumber Company in Siskiyou County, and on the holdings of the Diamond Match Company in Butte and Tehama counties. The full results of the McCloud work are embodied in a separate report by P. D. Kelleter. Recommendations made for the protection and slash burning on the lands of the Diamond Match Company were successfully applied during the season of 1904, a patrol being maintained, and several miles of trail and telephone lines constructed. A lookout station is still used, fire fighting tools kept stored at several points, and an emergency fire fighting force kept available. The full application of the plan, however, has been prevented by the opposition of the men in charge of the lumbering operations. As is so often the case, they object to even a slight change in methods, and stand in the way of reforms which are recommended by foresters and desired by the official heads of the companies.

Protection should begin with the logging area. The safe and economical disposal of slash is the most essential and difficult question. Practically all of the operating companies ignore the slash problem, and leave the tops and debris to dry out and furnish fuel to the first chance fire. Such fires not only destroy the reproduction and seed trees and injure the soil on cut-over land, but often run into and damage adjacent standing timber. Slash is always a menace, and unquestionably it should be burned at a time when the fire can be controlled without excessive expense. This is usually in early spring or late fall when the ground is moist and the slash is not dry as tinder. It should be piled in places and thrown back from seed trees and promising young growth. With careful preparation and by burning small blocks at a time and choosing a day when the air is calm or the wind favorable, slash burning can be successfully accomplished at a cost which should add but a few cents per thousand to the lumber manufactured. If slash burning is contemplated, care can be taken in felling so as to bunch the tops and save seed trees and reproduction.

Prevention is the keynote of economical protection from fire. On the reserves it is secured by a patrol of forest rangers and guards, by telephone lines and trails, by posting warning notices, by regulations regarding camp-fires and slashings, and by the enforcement of the fire laws. Fire lines are less effective in northern than in southern California, but in places they are an essential part of the fire system. All of the needed trails, telephone lines, and fire lines have not

been constructed, but are being put in as rapidly as possible. The people of California are fortunate in having such a large percentage of their forest land under Government protection, and they can depend upon it that the fourteen million acres of national forest will be carefully fire guarded, but the timber, water, and grazing resources, and related industries perpetuated on these lands.

In this connection, the experience of a number of timberland owners in southern Oregon is of interest. These firms, controlling much of the timber in the eastern part of Lane County, combined to protect their lands jointly. One of the companies assumed entire direction of the work, and all agreed to share the cost upon an acreage basis. About 500,000 acres were protected under this plan during the dry season of 1905. Patrols were established, and a number of short telephone lines constructed. Every large fire was reported, and a sufficient force sent out from the logging camps to extinguish it. The patrolmen put out many small fires unaided. The total area burned during the summer was less than 500 acres, and the total cost, including the wages of all extra men employed in fighting fire, was 8-3/10 mills per acre. The lumbermen concerned have voted unanimously to continue the plan this year, and a number of additional firms not included in the original agreement have asked to join. The whole is a very instructive illustration of effective protection, secured very cheaply thru the cooperation of timberland owners whose holdings adjoin.

Fire fighting.--A fire is a living thing with individual characteristics, and is influenced by so many factors that only general suggestions for fire fighting can be given.

A chaparral fire in a strong wind moves very rapidly and is exceedingly dangerous. To stop its direct advance should not be attempted, but advantage should be taken of ridge summits or of natural or artificial openings well in advance of the flames. At such points the ground can be cleared and the subsiding flames beaten out with wet gunny sacks or green boughs, or checked by throwing on fresh earth.

Fires in slash are quite as fierce as in chaparral, but are less difficult to control, since the slash is not impenetrable, and advantage can be taken of the log slides and old lumber roads. Back-firing is the safest and surest way of controlling a slash fire.

In mature timber the ordinary ground fires are not hard to control. If not too hot or too extensive the low line of flame can be beaten out. Otherwise, a narrow path can be raked to mineral soil thru the litter, and a back-fire set, or the flames beaten out as they die down at the path. Hand fire extinguishers are sometimes very effective with small timber fires.

Back-firing is always dangerous and should be used carefully and only by experienced men. There is a liability that the back-fire will get beyond control, or jump the break and run with the wind ahead of the main fire. On slopes it is particularly important that back-firing always be done down

hill. There is then less likelihood of the fire's assuming too large proportions, a smaller area will be burned over, and as the main fire burns most fiercely up hill, the points of greatest danger are made safe first, and the liability of burning cones and logs rolling down into burned country lessened.

One of the essentials of successful fire fighting is to stay with all fires until they are entirely out. A fire is frequently controlled and reported out, and then starts up later and burns with renewed energy.

The best time to fight all fires is in the night or early morning.

Conservative Cutting

The Government is committed by public policy to the conservative management of the forest reserves because of the necessity of protecting watersheds and maintaining a supply of timber for the future in much the same way as it is committed to cheap postal service regardless of whether the Post Office Department is self supporting. It is otherwise, however, with the private owner.

Altho many lumbermen are coming to realize the necessity for some system of fire protection on their lands, very few have as yet considered adopting that other essential principle of practical forestry, namely, conservative lumbering, or lumbering with a definite intention to provide for a second crop. The majority of private owners have logged their lands clean of everything possessing present market value. The logged-off lands have been sold or rented for grazing or have been held

without any definite notion as to their future use or value. In some cases they have reverted to the State. In no instance has a second cut either been provided for or expected; but in spite of this fact a few of the older concerns are now engaged in cutting timber from land which was cut over years ago, and from which all the timber at that time merchantable, was removed. The early logging, however, amounted to little more than a culling of the forest, and is not at all comparable to the clean logging of the present day. Former methods left more seed trees, more immature trees, and less slash to invite fire; and conditions were in every way more favorable toward second growth than they are now when the market permits the cutting of comparatively small trees at a profit. There is no likelihood that present methods, tho no more heedless than former methods, will permit a return to cut-over land within any reasonable time, and even then the forest will be much inferior to the present one. The present-day lumbermen must, therefore, deliberately provide for a second crop if he expects to cut over his land again, and to that end he must adopt methods similar to those in use on the forest reserves. It will, therefore, be of advantage to inquire whether, aside from producing the indirect benefits mentioned above, the Government system of management is also financially profitable; for only after proving that it is can it be successfully urged upon lumbermen. To illustrate both the methods employed and the financial results, it will be well to take specific examples, two timber sales from the Sierra Forest Reserve being selected.

The first tract is situated in the Greenhorn Mountains of the southern Sierras. The typical stand on the lower slopes and good soils contains a large percentage of sugar pine in mixture with yellow pine, white fir, and incense cedar. The stand may be divided roughly into three parts:

1. Young growth, below the merchantable size of 19 inches at the butt.

2. Thrifty timber, from 20 to 36 inches in diameter, of merchantable size but not yet mature.

3. Mature timber, over 36 inches in diameter.

The average number of trees of each class, per acre, is as follows:

	Sugar pine	Yellow pine	White pine	Cedar	All species
Young growth	194	23	537	168	922
Thrifty timber	3	1	5	2	11
Mature timber	3	1	2	1	7

On this tract the fir and cedar were cut to as small size as they are merchantable, namely, to a diameter of 19 inches. Taking both the mature and thrifty timber of these two species, the object was to reduce as far as possible the number of seed bearers of these comparatively valueless trees and hence increase the proportion of sugar and yellow pine in the second growth. The sugar and yellow pine were cut to 36 inches, taking only the mature timber of these two species. By referring to the table given above, it will be seen that this

method of cutting leaves 3 sugar pines and 1 yellow pine of the thrifty class per acre. These trees are now merchantable, but are left for the good of the future forest. They will produce and scatter seed of the kinds desired until the land is again cut over and at the same time increase steadily in size and value.

This method of logging permits an average cut of 19,474 board feet of all species per acre. The merchantable timber which is left, consists of 2,346 feet of sugar pine and 661 feet of yellow pine. Taking more exact figures from the survey of the tract, the following stand of pine and fir is left upon the average acre after logging:

Diameter	Sugar pine	Yellow pine	White fir
Inches			
5	162	19	455
4	25	3	70
9	..	..	6
12	7	1	..
16	..	..	6
25	2	..	..
30	..	1	..
33	1	..	..

We will assume that this tract is not cut again for fifty years. Using very conservative tables of growth, prepared by the Forest Service, the stand upon the average acre will then be:

Diameter	Sugar pine	Yellow pine	White fir
Inches			
7	..	..	455
10	162	..	..
11	..	19	..
14	25	..	..
16	..	3	6
22	..	1	6
23	7	..	..
32	2	..	..
35	..	1	..
38	1	..	..

While more or less of the smaller growth is destroyed in logging, the larger trees which are not cut are usually, under the reserve regulations, left intact. Among these thrifty pines, moreover, the loss from windthrow is very slight. With 4 seed-bearing pines left, per acre, and continuous protection against fire, the new stand should contain, besides the trees given in the above table, an abundance of seedlings and saplings in the open spaces.

At fifty years after cutting, therefore, assuming the same merchantable limit of 19 inches, the stand per acre will consist of 8,270 board feet of sugar pine, 2,890 feet of yellow pine, and 3,600 feet of white fir. Incense cedar is not estimated in the absence of satisfactory growth tables.

The next point to examine is how the Government stands financially upon this operation. In each acre it has invested 2,346 feet of sugar pine and 661 feet of yellow pine, now merchantable. The sale was made on the basis of an apparent stumpage price of $2.50 for sugar pine and $2 for yellow pine, which would amount to $7.13 per acre. The actual stumpage price, however, was 50 cents more in each case, for the following reason:

As was shown in the discussion of logging the Government requires the purchaser to pile brush ready for burning and to comply with other necessary regulations which together cost, in the Sierras, on the average of 50 cents for every thousand feet of timber cut. It is evident that by not enforcing these regulations the Government would be able to sell the same timber at an advance of 50 cents per thousand. The timber is worth, therefore, 50 cents a thousand more than the price named in the contract; and the actual investment in merchantable timber left is therefore, $8.63 per acre instead of $7.13.

Similarly, the Government sold the 19,474 feet per acre for a certain price, but under restrictions which cost 50 cents a thousand feet. If it were striving simply to get the greatest immediate return, the Government could have received 19,474 x 50 cents or $9.74 per acre more than it did receive. This amount must, therefore, be considered as invested. In addition, it invests 10 cents a thousand or $1.95 to burn the piles of slash; and finally there is the cost of administration and protection which may be placed at 1 cent per acre, slightly more than it is at present.

At 3 per cent compounded annually: $8.63, the value of the standing merchantable timber would amount in 50 years to	$37.83
$9.74, the cost of piling brush, etc. would amount in 50 years to	42.70
$1.95, the cost of burning brush, would amount in 50 years to	8.55
1 cent invested annually for protection would amount in 50 years to	1.13
The total investment per acre at the end of 50 years is thus	$90.21

The estimated stand per acre at the end of 50 years is

Sugar pine	8,270 feet
Yellow pine	2,890 "
White fir	3,600 "

Therefore, in order that the Government may come out even in the operation, stumpage values must more than triple in 50 years. If in 1956 sugar pine stumpage is worth $7.73; yellow pine, $6.19; and white fir, $2.32; the original investment will be returned with interest. Any further increase in stumpage values will be clear gain.

A second illustration is taken from the headquarters of Fresno River in the Central Sierras. Here a sale has been made in a fine stand of yellow pine in mixture with some sugar

pine, white fir, and cedar. Roughly dividing the stand into three parts as before, the average acre contains the following trees:

	Sugar pine	Yellow pine	White fir	Cedar	All species
Young growth under 19"	17	107	24	109	257
Thrifty timber 20" to 36"	1	5	1	5	12
Mature timber over 36"	1	5	1	1	8

On this tract also fir and cedar were cut to as small a diameter, 19 inches, as they are merchantable to better the chances for good reproduction of sugar and yellow pine. The latter were cut to 36 inches only, leaving 6 trees of the "thrifty timber" class on each acre. These trees are now merchantable and contain 900 and 5,875 board feet of sugar and yellow pine respectively. The stumpage prices mentioned in this sale were $2 for sugar pine and $1.50 for yellow pine. They thus have a present money value of $10.60 plus the 50 cents per thousand allowed for piling, or $13.99 all told. These trees represent a sacrifice on investment in the land for the perpetuation and renewal of the forest. They will seed the ground continuously with sugar and yellow pine. At the same time they will increase steadily themselves in size and commercial value. It should be noted that the six merchantable pines which are left are right in the period when they are growing most rapidly in volume. With an increasing proportion of heartwood and clear bole they are, moreover, steadily attaining a finer quality as timber.

Even reserving these trees, a cut on this heavily timbered tract of 27,081 board feet per acre is possible with a money yield of $40.87.

Let us assume that this tract also is left for fifty years before a second cut is made. Applying the same growth tables as in the former case, the stand of merchantable timber per acre at the end of that period will be 6,020 feet of sugar pine, 16,580 feet of yellow pine, and 1,020 feet of white fir. It is useless to attempt to outline what the method of cutting will be at that time. The essential point is that the merchantable timber will be there to be cut if deemed advisable.

Let us apply the financial test to this case also.

$13.99, the value of the timber now merchantable but left standing, compounded at 3 per cent, would amount in fifty years to	$61.33
50¢ per thousand feet for piling, etc., or $13.54 on land cutting 27,081 feet would amount in fifty years to	59.40
10¢ per thousand feet for burning slash, or $2.71 per acre on land cutting 27,081 feet, would amount in fifty years to	11.88
1 cent per annum for administration and protection becomes in fifty years	1.13
The total investment per acre at the end of the period would then be	$133.74

The estimated stand of timber, cedar not included, at the end of that time is as follows:

6,020 feet of sugar pine

16,580 feet of yellow pine

1,020 feet of white fir

It is evident that here also an average increase of over 300 per cent in stumpage prices during the next fifty years is necessary to make the investment sound. In other words, if sugar pine stumpage is worth $6.94 per thousand feet in this locality in 1956, yellow pine $5.59, and white fir $2.63, the Government will recover the full amount invested at compound interest. Any further increase will be a net gain.

The private owner is necessarily in a more difficult position than the Government in adopting conservative methods of cutting. He has taxes to pay where the Government has none, altho the 10 per cent of the gross revenues from the reserves, paid to the counties included might be regarded as a tax. The cost of protecting his land is necessarily higher because it must be done upon a comparatively small scale; and he must consider the market value of his cut-over land, which the Government can ignore since its ownership of the reserves is perpetual. Cut-over timberland, under average conditions, is worth $2 an acre and assessed at $1.50. At a rate of 2 per cent the annual tax is 3 cents an acre. The protection of a private tract of average size should be placed at fully twice the cost of protecting the reserves, or 2 cents an acre.

Starting from this basis, let us substitute a private owner for the Government in the first operation described above. In the first place he would, like the Government, invest $8.63 per acre in merchantable timber left uncut. He would invest 50 cents a thousand in piling brush, etc., and 10 cents a

thousand in burning the piles, or $9.74 and $1.95 respectively. Unlike the Government, he invests the value of his cut-over land, or $2, and there is finally invested an annual charge of 5 cents, 3 for taxes and 2 for protection. Carrying all these sums forward fifty years at 3 per cent compound interest, the total investment per acre at the end of that period is $103.49. If the land itself is still worth $2, we have $101.49 to be covered by the value of the timber. The 8,270 feet of sugar pine, 2,890 feet of yellow pine, and 3,600 feet of white fir, which will be ripe for cutting on each acre at the end of fifty years, must therefore, have stumpage values of $8.70, $6.96, and $2.61 respectively if the investment is to prove financially sound.

Substituting the private owner for the Government in the second illustration, and performing the computation in the same way, we find that sugar pine stumpage must advance in fifty years to $7.70, yellow pine to $5.27, and white fir to $2.89 if the investment is to be profitable.*

These figures may not seem very encouraging to those who are actively engaged in lumbering and who are considering the advisablility of adopting forestry principles in the management of their timberlands; but there are many additional points that must be considered besides this bare financial statement before the proposition can be wholly rejected.

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*If these stumpage prices actually prevail fifty years hence, the forest owner who is holding his timber for a rise in value will realize about 2-1/2 to 3 per cent.
(Second illustration

$$\frac{20 \text{ sq.ft} \times \$6 \text{ (average stumpage price)}}{40.87} = 2\text{-}1/2 \text{ per cent})$$

In the first place it is becoming increasingly apparent that a system of fire protection must be organized not simply or chiefly for the sake of the cut-over land, but for the sake of the virgin timber and the plant. A portion, therefore, of the amount charged against the second crop as invested in fire protection, should be considered rather as insurance on the virgin timber and plant. The financial result is the same. The money spent on protection is invested instead of realized, whether it is charged to the present operation or to the future operation, but once it is admitted that the charge for fire protection is a necessary expenditure in any extent, it is evident that the leaving of immature trees to form a second crop becomes less a tax, and is considerably more worth while.

We have seen, furthermore, that the typical lumbering operation in the sugar and yellow pine belt requires a very large initial investment. In many cases an outlay of $500,000 or even $750,000 has been required to put the entire plant in readiness for operation. To recover this initial expenditure, nearly every lumber firm includes a depreciation charge of from $1 to $2 per thousand feet in the cost of logging. That is, after a run of say twenty years, the timber will be exhausted and the logging, railroad, mill, and other equipment will be so much worthless dirt and scrap iron. Each thousand feet of timber logged must, therefore, pay one or two dollars to a sinking fund which will, when the entire tract is cut, cover the cost of the original investment.

Now if, under conservative cutting, a tract can be logged over a second time immediately or very soon after the first

cut is completed, the length of service of the plant will not be limited to the time required for the first cut, but will be prolonged indefinitely. What becomes then of the depreciation charge? It can not be wholly eliminated, but would it not, under these conditions, be greatly reduced? If a second cut is possible, the cost of the plant would not be borne by the billion feet of virgin timber, but by, say, 900,000,000 feet of virgin timber plus 700,000,000 feet of second-growth timber; and once conservative management is installed, there is the possible third cut to be reckoned with. It is not impossible that the lumberman who cuts conservatively will find that the reduction in his depreciation charge more than offsets the extra cost of logging due to changed methods, and that his margin of profit on the operation instead of being reduced, will be actually increased. The enormous investment required for successful lumbering in this region is one of the strongest arguments that can be offered for conservative methods. Any step that will lengthen the term of service of these expensive plants is worthy of there consideration.

Another suggestion is offered. The greatest problem of the Sierra lumbermen, almost without exception, is the disposal of his low-grade stock. The western markets are glutted and the transportation charges make its shipment for any distance out of the question. Many firms handle from 30 to 60 per cent of their annual cut at an actual loss. Now under any method of conservative cutting, the trees which are reserved for the second crop are the youngest and smallest, with the largest proportion of sapwood and of knotty lumber. The merchantable timber which

is left would cut mainly low-grade stock. In other words, it is believed that the sugar and yellow pine lumberman will find an additional argument for conservative logging in a higher percentage of the better grades in his annual cut, and hence in the higher average selling price which it will command.

Stumpage

The final and most important point of all in favor of conservative lumbering lies in the fact that the end of the floating timber is in sight, and that stumpage prices are rapidly appreciating.

The essential factor in lumbering up to the present in the Sierras and northern cross ranges has been the ease in acquiring timberland and, hence, cheap stumpage. Under the very liberal land and timber laws of the Federal Government, large holdings have been easily acquired at very slight expense. Much of the timber now owned by lumber companies and investors was acquired at an average cost of 10 to 40 cents a thousand feet, pine stumpage only being figured, and other species not considered at all. Hundreds of homesteaders and small timber locators, unable to operate themselves or to hold and pay taxes on their land, have been selling out to large operators at prices dictated by the latter. In many cases the small owners have been forced to sell because they were surrounded by large operators and unable to get their timber to market. As an instance of this character, a tract containing 21,000,000 feet of sugar and yellow pine in the central Sierras, which has been held for some years, was sold in 1905 to the lumber company whose holdings surrounded it, and

which controlled every outlet, for $5,000, or approximately 20 cents a thousand feet.

As long as cheap stumpage is obtainable, there is obviously no incentive to cut conservatively. Under such conditions, the best policy is clearly to log for the greatest immediate return and then move to virgin timber. The important question in the case is: how long will this situation continue?

Of the total area of approximately 17,080,000 acres included in this timber belt, 8,612,000 acres are owned and permanently reserves by the United States; 880,000 acres are owned by the Government and withdrawn from settlement, pending examination and probable addition to the reserves; 1,426,000 acres are owned by the railroads, which are also adopting the policy of permanent ownership and conservation. There are 1,280,000 acres of Government land still open for settlement. These are mainly, however, barren, discarded areas, bearing no timber, and can be largely disregarded.

Within this belt there are, all told, 4,874,000 acres of land under patent or claim. Of this, approximately 1,500,000 acres are owned by large operators, now actively exploiting the timber. Approximately 150,000 acres are owned by small mills, also actively engaged in cutting. About 900,000 acres are owned by timberland investors, men who are not now logging, but are holding land and stumpage for future exploitation or for rise in value. There remain 2,319,000 acres whichaare mainly in small holdings. From this must be deducted all agricultural and grazing lands and all mineral entries. The balance represents the floating timberland, the small holdings which may

be considered as on the stumpage market, the price of which is steadily rising.

The changing situation in respect to timberlands is illustrated most forcibly by the history of stumpage prices in the sugar and yellow pine belt during the last fifteen years. Fifteen years ago, as far as any stumpage price was recognized for these two species, it was not more than 10 to 20 cents per thousand feet. Five to eight years ago, a good many tracts were cruised and purchased on the basis of 50 cents per thousand for the pine timber only. To-day in the open market stumpage is held at from $1 to $2 per thousand feet. In some cases $2.50 has been paid for sugar pine and $2 for yellow pine on the forest reserves, plus an additional 50 cents per thousand feet in the cost of logging, due to federal regulations. Within the last fifteen years, there has been an average increase from 15 cents to $1.50, or 900 per cent.

It is recognized that cheap stumpage is now obtainable only in small, scattered bodies. With the keen competition between buyers of timberland, it is harder and harder to secure stumpage at any price, since the available timberlands are passing rapidly into strong hands, which are holding them for future exploitation. There are several localities in this belt where firms which have completed the logging of their own holdings, are forced to go out of business unless forest reserve timber is available. Oregon and Washington will, of course, offer an outlet for some time to come, but the changed conditions which we have noted in California are taking place in those States also, the more slowly. The essential point to note is that, while more

or less timber can be picked up here and there, it will be increasingly difficult, as the present tracts are logged off, to secure virgin timber in sufficient bodies to justify a plant and an operation on the same scale as the present. It will certainly be impossible to do so at anything like the same stumpage rates which have heretofore prevailed. The time is approaching rapidly when new stumpage can be secured only from the federal reserves at the highest market price, unless conservative cutting is practised in the lands now being logged, so that a second cut can be made when the virgin timber is exhausted. Unless the private owner cuts his own timber conservatively, under some such plan of long time investment as that outlined, he will in all probability be forced, when his virgin timber is exhausted, either to go out of business or to buy stumpage from the reserves at the highest prevailing prices, and under regulations that will require an additional expense of fully 50 cents a thousand feet in logging. In other words, the private owner now has the opportunity of investing the cost of conservative cutting in his own land rather than in the Government's land. He may reap himself the increase in stumpage prices rather than waiting for it to accrue and then pay it over to the Government.

Conclusion

Fire protection is the point of first importance. The utmost care and watchfulness should be required to prevent fires from escaping from camps, locomotives, and donkey engines, and to detect and extinguish every fire as soon as it is started. Locomotives and donkey engines should invariably carry efficient

spark arresters. Outside of the logging operations, patrol during the dry season is always the most effective method of protection. It should be supplemented as far as possible by trails and telephones to make the tract accessible.

Grazing upon freshly-cut lands is harmful, since it is liable to retard the restocking of the ground, After ten or twelve years have passed, sufficient to give the seedlings a good start, limited grazing will do no harm, and frequently can be made a source of considerable revenue. From 1 to 5 cents per acre has been secured annually by a number of firms in the Sierras by leasing grazing privildges upon their cut-over lands.

Next to protection, the essential point in conservative management is to have enough of the younger and thriftier timber to furnish sufficient seed of the valuable trees and to form the basis for a second cut. No hard and fast rule can be framed to meet this requirement. In many cases the simplest and most practical method will be to follow a diameter limit in cutting. On many tracts thru the Sierras, cutting to 50 inches will leave a sufficient stand of young pine timber on the ground. In other cases it will be inadvisable to follow any fixt diameter. Let the fallers leave here and there a group of trees which are mainly of the younger and thriftier class and cut clean around them. These groups will quickly seed the intervening spaces and will yield a good cut of timber when the land is logged again.

The final point is to protect the young growth and the trees which are to be left as fully as possible, both during and after logging. This requires close supervision of the logging crews to prevent unnecessary injury in felling, slinging rigging

for donkey engines, and handling logs. It requires also some method of disposing of slash. The latter should be as cheap and simple as possible consistent with fair thoroness in removing the small, inflammable material, and with little damage to the remaining trees and seedlings which it is the object of the work to protect. Piling slash, as required in the forest reserves, is expensive, having never been done for less than 30 cents a thousand feet. In some localities, however, where young growth is dense and small timber is scattered over the ground, it is the only safe method applicable.

In more open country, especially where the timber and young growth are bunched, it is often sufficient simply to throw the slash when logging into the openings, away from anything which should be protected, and then fire it without piling. This method is much less expensive than piling, but on many of the open pine lands in the northern part of this timber belt will secure almost as satisfactory results. It is wholly unnecessary to burn large tops and butts. With the small, inflammable material removed, the large prices above offer no menace to the forest.

Clean logging is not so much a part of conservative management as of good lumbering. It is now practised by many private firms to a degree equal or nearly equal to that required by the Government.

As illustrating the various points mentioned, the policy adopted by the McCloud Lumber Company at the suggestion of the Forest Service is of special interest. This firm has decided to hold all its cut-over lands and plans to log them again

about thirty years after the first cut. All of its holdings are protected from fire by patrols. Each patrolman covers from 40,000 to 70,000 acres. A telephone line has been constructed to enable the patrols to communicate with headquarters promptly when extra help is needed to fight forest fires. Stations for storing fire-fighting tools are being built at strategic points, usually about 3 to the township.

In addition to these measures, fire lines burned out to a width of 200 feet and designed to serve as vantage points in fighting fires have been constructed on a portion of the tract. These lines cost from $12 to $15 per mile and will be used only to protect the most valuable bodies of growing timber. Twenty miles of line are sufficient for a township. The total cost of this system of protection during the last year was 2 cents an acre.

The loggers employed by this Company are instructed to cut no trees under 30 inches in diameter at the butt. This method of logging leaves a great deal of young, thrifty timber on the cut-over lands, much of it standing in compact bunches which are left intact.

Logging in this comparatively level country is done with "Big wheels". A space is cleared for their operation on each side of the logs, the slash being thrown up in windrows to the left and right. The swampers are required, in clearing out for the big wheels, to throw the slash away from the remaining trees and valuable young growth. After the ground has been moistened by the first fall rains, the windrows of slash are burned with practically no additional piling. The cost of this burning last year was 1-1/2 cents a thousand feet or 23 cents an acre.

Simple as it is, this system covers the essential points of conservative management. A fine stand of young timber is left to reseed the ground and yield a profitable cut when the land is logged again. The burning of the slash and the system of patrols provide for the protection of this young stand. The sums expended for these purposes amount simply to an insurance of the future cut of timber.

Conservative methods of lumbering must necessarily begin with the larger owners holding tracts of 20,000 acres or more. Only on areas of this size will it be possible, under the plan of holding logged-over lands for a second cut, to keep the plant in continuous or nearly continuous operation. Furthermore, the average cost of protection per acre is always reduced as the size of the tract increases, and the work can be done on a larger scale.

Conservative methods are not now possible for the small owner. Under the changed market conditions, however, which are gradually coming about, it is believed that lands, which are lightly and carefully logged, will in time acquire a distinct market value as contrasted with clean-cut lands. Conservative cutting may in this way ultimately pay the small operator as well as the large operator.

The State

The interest of the State in the introduction of practical forestry in the Sierras is a purely economic interest in the permanence of one of its foremost industries and sources of wealth. The enormous body of natural timber-producing land in this region forms one of California's greatest resources. If this resource can be made permanent, like agriculture and horticulture, the gain to the State as a whole in wealth and in the stability of its industries will be incalculable. Some portions of this naturally timbered area are now in danger, thru hard logging and fires, of turning into unproductive barrens, fit only for sheep range. Such a result, if general, would certainly react upon the whole State in the loss of population and taxable property. The point where the State can be of most assistance and where its help is most needed in encouraging the practise of conservative methods is in a thoro going system of protection against fire. The private owner needs the aid of the State in the problem of protection. Especially is this necessary because the protection of any forested area depends so largely upon the protection of the areas which surround it. An owner may protect his own tract most carefully and still be in constant danger from his neighbors. It is right here that the State, in the exercise of its police powers, should come to his assistance.

Furthermore, with California's long seasonal drought and with the established custom in many localities of firing the woods for one purpose or another, the task of protection is a

large one. It demands the cooperation of the State with the Federal Government and the private owner; and no single step would be more effective in promoting the adoption of conservative methods by timberland owners than a system of protection which will make their holdings secure against fire.

An excellent start has been made by the State of California in the creation of a State Board of Forestry with State Forester and Fire Warden. The weakness in the present law is that the actual local work in fighting fires is left almost wholly to voluntary, unpaid wardens, and hence can never be effective.

The State system should be extended to include paid wardens in the various localities where fires are most numerous, and to provide an emergency fund which can be drawn upon to hire necessary assistance. These changes would make it an effective means of protection. By decisive action along these lines, the State can most effectively encourage the practice of conservative methods by timberland owners, and most surely safeguard the permanence of its timber resources.